

**RETHINKING CONSTRUCTION
MANAGEMENT
PRACTICES TO ATTAIN
SUSTAINABLE DEVELOPMENT
GOALS**

(VOLUME - 1)

Chief Editor

Mohd Asim

Assistant Professor, Department of Civil Engineering, Integral
University, Lucknow, Uttar Pradesh, India

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CHAPTER

8

**BARRIERS AND OPPORTUNITIES IN
ADMINISTERING OFFSITE CONSTRUCTION
IN LATEST CONSTRUCTION PROJECTS OF
LUCKNOW (U.P)**



Arichandran. R

M. Tech Research Scholar, Department of Civil Engineering, Integral
University, Lucknow, Uttar Pradesh, India

Mohd Asim

Assistant Professor, Department of Civil Engineering, Integral
University, Lucknow, Uttar Pradesh, India

Syed Aqeel Ahmad

Professor and Head, Department of Civil Engineering, Integral
University, Lucknow, Uttar Pradesh, India

Abstract

Offsite manufacturing Construction refers to the manufacturing, planning, design, fabrication, precast and assembly of the building elements at one location and those elements are shifted to the site and assembled by using crane. In this methods manufacturing teams are produce the product in excellent quality because the works are performed in ground level only, the quality of individual elements and their sizes measured easily. Here is the curing of RCC elements can controlled, there is no high level height of scaffolding work required. The materials wastage is less. The study is performed with reinforcement of piles, pile cap, foundations, columns and beams of RCC elements as per Indian code practices to analysis, investigate & identify the barriers factors during the execution work when individual elements of RCC structure by precast elements, and also identified the opportunities of offsite construction methods to adopt in the building structures or by individuals.

Keywords: Offsite construction, barriers, precast concrete, modular construction, prefabrication.

Introduction

The current population of India is around 1419052026, approximately say 141.90 Crores; May 21, 2023, based on World meter elaboration of the latest United Nations data. India population is equivalent to 17.7% of the total world population. As per the 2011 Census, 30% of India's population lived in urban areas, which is expected to reach 40% by 2030. Urban Housing shortage exists due to a big gap between demand and availability of housing in the cities, both in terms of number and quality. As per the technical study conducted by MHUPA (Ministry of Housing and Urban Poverty Alleviation), the urban housing shortage in India is currently estimated at approximately 19 million. This gap is expected to further widen to an estimated 38 million homes by 2030 largely due to the rising population and increased urbanization. Gradually increase of population and shortage resources like steel, cement, sand, aggregates etc, need of infrastructures and homes are to be made through sustainable construction methods by timely with quality and economically as requirement of the demand, so instead of onsite construction, offsite construction is alternate technology for the best solution for current and upcoming times. Offsite manufacturing Construction refers to the manufacturing, planning, design, fabrication, precast by RCC and assembly of the building elements at one location and those elements are shifted to the site and assembled by using crane. In this methods manufacturing teams are produce the product in excellent quality because the works are performed in ground level only, the quality of individual elements and their sizes measured easily. Here is the curing of RCC elements can controlled, there is no high level height of scaffolding work required. The materials wastage is less. This paper discusses the Barriers and opportunities in endorsing administering offsite construction in Construction of Integrated New Terminal buildings with elevated road project, at CCSI Airport, Terminal-03, Amousi; Lucknow. This construction project site is approximately 20% works are doing by offsite construction such as RCC Precast girders at elevated road works, Steel Roof Truss at terminal buildings and other miscellaneous works and which all quantities are taken only structure activities except the finishing works.

Literature Review

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highlights some of the barriers and drivers facing the Indian construction industry. The data was gathered through a survey of 17 high level managers from some of the largest stakeholder organizations of the construction sector in India. The influence of time and cost has been highlighted as a major factor fueling the adoption of offsite construction. However, the influence of current planning systems and the need for a paradigm shift are some of the prominent barriers towards the adoption of offsite techniques. Publication with Date: 25th International Congress on Condition Monitoring and Diagnostic Engineering, IOP Publishing; Journal of Physics: Conference Series 364 (2012) 012109; doi:10.1088/1742-6596/364/1/012109

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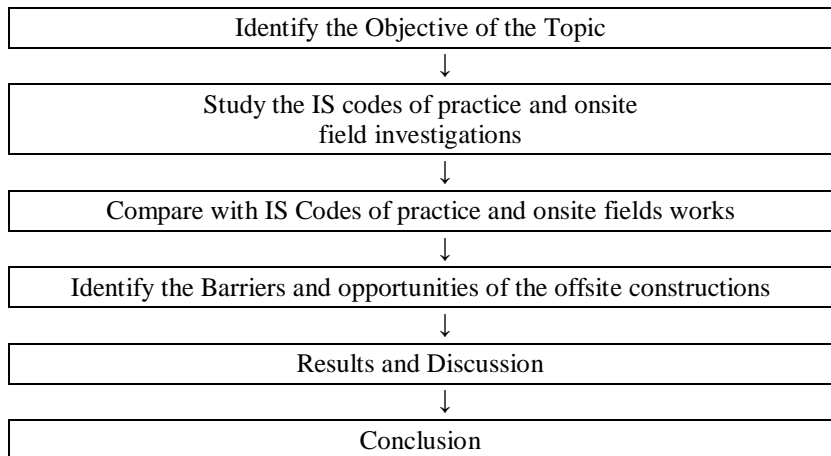
is utilized in devising the framework. This framework is tested and validated on a case study where offsite technologies are used; Publication with Date: Science Direct; Procedia Engineering 196 (2017) 135-143; Creative Construction Conference 2017, CCC 2017, 19-22 June 2017, Primosten, Croatia

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also discussed here ; Publication with Date: International Research Journal of Engineering and Technology (IRJET); Volume: 05 Issue: 01; Jan-2018 ; www.irjet.net; e-ISSN: 2395-0056; p-ISSN: 2395-0072

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Methodology



Discussions

1. Discussion on Barriers to adopt individual elements of the RCC structure by offsite construction according to the IS Codes practices
 2. Discussion on Opportunities endorsing offsite construction elements
1. **Discussion on Barriers to Adopt Individual Elements of the RCC Structure by Offsite Construction According to IS Codes**

The following RCC members taken for this study to Barriers towards the adoption of offsite construction elements at site.

1. Study with the foundation Reinforcement bars

2. Study with the pile& Pile cap
3. Study with the Column Reinforcement bars
4. Study with the Beam Reinforcement bars

The said above members are main parts of the structure so that those members are taken for research. The study is performed with reinforcement of piles, pile cap, foundations, columns and beams of RCC elements to find out the barriers factors behind during the execution work when individual RCC elements by precast. By doing work by steel structure with prefabricated columns and beams like ISMC, ISMC sections, these works are common in practice, for steel structure works every members are joined with bolts and nuts, but not in the RCC members like that. The standard length of the reinforcement steel bars length for RCC works are 12 meter from the market. The execution of the reinforcement work for lateral members and vertical members by (Bar bending schedule) BBS engineer, according code practice lap splices are have to provide in the lap zone of the section only. So the cutting, bending and tying of the bars are by using code practice only.

SP : 34(S&T)-1987

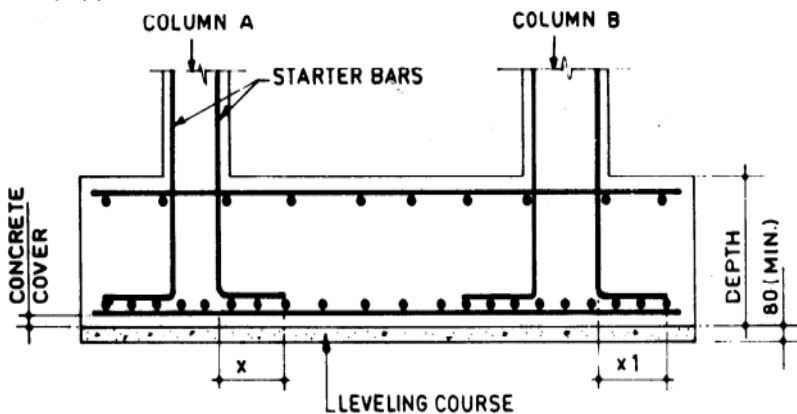


Fig 1: Typical Section for Column Reinforcement as per SP34-1987

1) Study With the Foundation Reinforcement

Fig 1: The typical sectional elevation of foundation details given in SP34-1987, according the section 1st work foundation steel work to be executed at site. After the foundation steel work completed, then column steel dowels are placed from the bottom of the foundation. Both foundation and columns are separate members. Firstly the RCC foundation will be concrete casted in 1st pour element after completion of reinforcement and shuttering work, but columns are concrete casted 2nd pour only after completion of steel and

shuttering work.

Note: The reason of barrier to precast elements (Offsite construction methods) is columns steel dowels bars at construction joints are in between foundation and columns because lifting and erection by mechanical method by crane is impossible.

2) Study With the Piles and Pile Cap Reinforcement

In fig 2: showed as during the erection of pile reinforcement work, the steel dowels are interconnect with pile cap and during the pile cap reinforcement work column steel dowels are also interconnected.

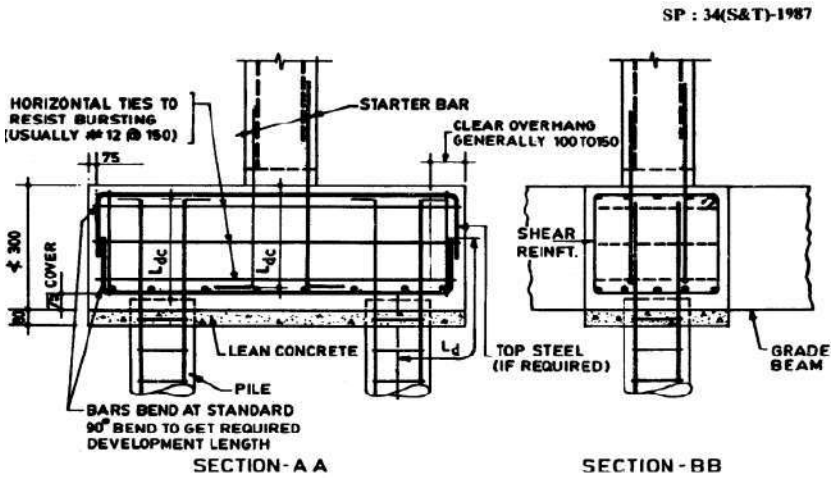


Fig 2: Typical Section for Piles and pile Cap per SP34

From fig.1 and fig. 2 every individual RCC members piles, pile cap and columns are interconnected by of the steel reinforcement bars dowels with exist or new members. Due the factor of steel dowels at construction joints are impossible for lifting and erection by mechanical crane when the construction is preferred for precast construction methods by individual members

Note: The reason of barrier to precast elements (Offsite construction methods) is pile steel dowels bars at construction joints are in between pile and pile cap and between pile cap and column, so lifting and erection by mhanical method by crane is impossible.

3) Study With The Column Reinforcement Bars As Per Is Codes

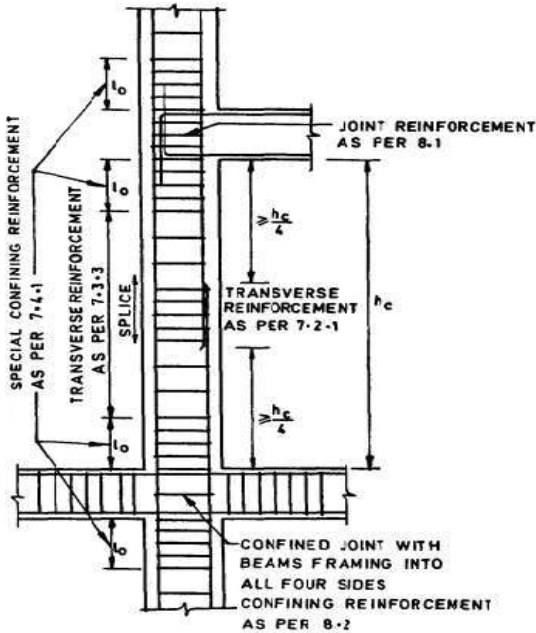


Fig 3: Typical Column Reinforcement (IS 13920:1993)

Conditions:

From fig.3, the requirement of column steels are

- here h_c is the Column clear Span, Transverse Reinforcement or lap zone (Splices) are coming at middle of the Column
- 50% of the bars are staggered at a sections
- As per section every floor of column and walls steel dowels required

Why impossible to offsite construction by individual column members?

- Due to lap splices of the steel bars coming at mid of the RCC columns in every floors, so that the columns are not produce by offsite construction method by precast.
- Steel dowels are there in between floors and columns junction
- Lifting and erection by crane is impossibility because the steel dowels at every construction joints
- In steel structure members like beam and columns by ISMB or ISMC are every joints are connected by bolts and nuts but in RCC members no possibility available

Note: The reason of barrier to precast elements (Offsite construction methods) are considered as i) Laps splices are at mid of the columns ii) Steel dowels are at construction joints iii) steel dowels at every construction joints iv) There will be no option to connect of precast members by bolts and nuts.

Typical Column Vertical Reinforcement for multi-storeyed buildings

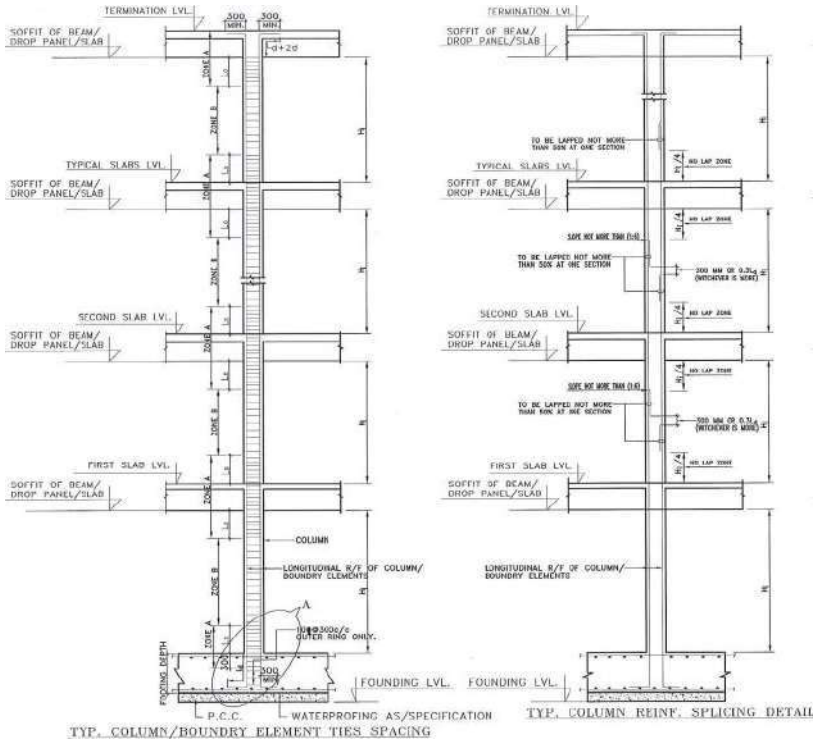


Fig 4: Typical Column Vertical Reinforcement for multi-storeyed buildings As per IS 13920:1993

Fig 4: is the example for RCC Structure sectional elevation of high rise building or multi-storeyed buildings, here we observed the lap splices at mid of the columns at every floors.

- The beams and columns are interconnected with reinforcement steel bars.
- 50% of the bars are staggered/spliced at a middle of the columns.

4) Study with the Beam Reinforcement of RCC Structure

i) **Development length of the end of the beams at support As per IS 13920:1993**

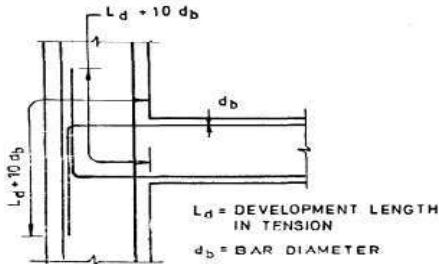


FIG. 1 ANCHORAGE OF BEAM BARS IN AN EXTERNAL JOINT

Fig 5: Development length of the beams bars at end joints

Conditions of Beam reinforcement from fig.5

- In an external joint, both the top and the bottom bars of the beam shall be provided with anchorage length, beyond the inner face of the column, equal to the development length in tension plus 10 times the bar diameter the allowance for 90 degree bend.
- In an internal joint, both face bars of the beam shall be taken continuously through the column.

ii) Lap Splices at Clear span of the beams As per IS 13920:1993

Conditions

- The lap length shall not be less than the bar development length in tension (fig.6)

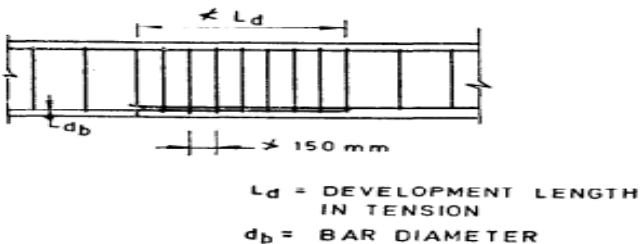


FIG. 2 LAP, SPLICE IN BEAM

Fig 6: Lab splice of the beams bars

- Lap splices shall not be provided
 - within a joint,
 - within a distance of $2d$ from joint face, where d is the depth of the member
 - Within a quarter length of the member where flexural yielding may generally occur under the effect of earthquake forces.

- Not more than 50 percent of the bars shall be spliced at one section.
- The lap splices to provide at mid of the span for Top Reinforcement of the beams and at L/3rd portion of the joint of clear span for the bottom Reinforcement; where L is clear span of the beam.

Note: The above conditions are barriers to produce of the precast elements by RCC because practically there is not possible.

1. Field Study/Investigation Data From Lucknow International Airport (Ccsi Airport)



Fig 7: Raft foundation

The **fig 7.** Is the Raft foundation work, Reinforcement work of raft on 95% completed, column vertical steel dowels are placed. The picture is showing the Raft foundation Reinforcement work on progress. The area of the work is approximate more than 1000 Sqm The foundation will be casted by RCC. The barrier we can consider for offsite construction is Reinforcement dowels for column. Here the construction joint is come at the Raft foundation top at all columns location

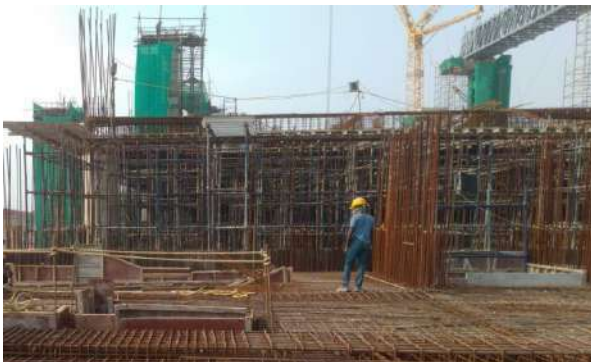


Fig 8: Roof Beam Reinforcement

The **fig 8:** is Elevation picture showing the Roof Continuous Beams Reinforcement work completed. The barriers was observed for offsite construction are Development length of the beams of the bars at end of the beams $L_d + 10 \text{ dia}$; Lap zones of the of the top Reinforcement of the bars at mid and bottom reinforcement of the bars at $L/3$ from face of the beams; the 150% of laps bars to be staggered at a section.

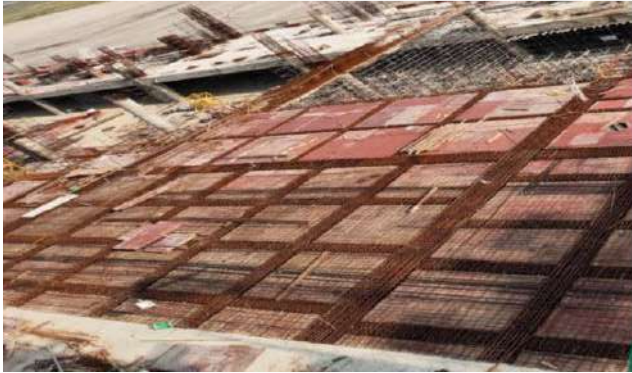


Fig 9: Roof Continuous Beam Reinforcement

The **fig 9:** picture top view is showing that Roof Beams are continued Beam Reinforcement work at both X axis and Y axis direction the barriers we can consider for offsite construction are Every beams are inter connected

- Lap zones of the of the top Reinforcement of the bars at mid and bottom reinforcement of the bars at $L/3$ from face of the beams
- At mid joints of beams Reinforcement bars to be continued.
- 50% of bars to be staggered

Suggestion: Study of IS codes with Site Investigation

According to IS codes practices and field study with the members of pile, foundation, Column and Beams, the study suggested that;

- a) RCC structure buildings are not constructed by the individual elements by precast; because identified that steel dowels at every joints of the construction are the main barrier to adopt offsite construction methods, and erection by lifting cranes is not possibility.
- b) In steel structure members like beam and columns by ISMB or ISMC are every joints are connected by bolts and nuts but in RCC members no possibility available.
- c) The main factors of the barrier to adopt by precast through RCC for all individual members are considered as factors of development

length, lap splices (Lap zones) of the sections, Steel dowels at construction joint one member to another member and conditions of the cutting, bending from 12m of standard length of the steel bars are mandatory.

- d) So this study is encourage alternate methods to adopt for RCC Buildings structure that is the method offsite construction like volumetric modular construction method to deliver products without any barriers.

2. Discussion On Opportunities Endorsing Offsite Construction Elements At Site

The study report of Case Study on Barriers to adopt individual elements of the RCC structure by offsite construction according to the IS Codes (Page No 3 to 9 of this paper) have clearly explained that offsite construction by individual elements are not possible wherever the steel dowels are placed at exist construction joints of the RCC structure. So we can consider the following works for opportunities offsite construction wherever no steel dowels at the joints of RCC Precast members/ prefabricated steel members

1. RCC Precast Girders or Prefabricated steel girders at Elevated Road works
2. Precast RE Wall panels at Ramp connect with elevated road
3. Prefabricated steel modular sections at various jobs

Field study 1: Investigation at elevated road work at Lucknow International Airport



Fig 10: Pedestal above Pier Cap

Fig 10: the picture showing that the work is completed up to pedestals after the pier cap. After the pedestal there is no Reinforcement dowels at the joints between pedestals and next work of the erection work of precast girders.

Note: Here is no barrier to lifting and erection of precast girders, because base of the erection point having no steel dowels or laps.



Fig 11: Precast RCC Girder

Fig 11: The precast RCC Girders are made by offsite construction method. Here the reinforcement, shuttering and RCC work are done at ground level. The curing of elements done at ground level and also 100% quality checkup done by quality team at ground level. There will be no special requirement of high height of ladders, scaffolding works etc.

After the achievement of the compressive strength of the concrete elements, those are shifted to the site. The lifting and erection works for the elements are planned proper before proceed to start the work.



Fig 12: RCC Precast Girders Erection

The **fig 12:** individual precast RCC Girders are lifting by cranes and erection work completed at site.

The base of the girders was made by RCC pedestals, this was not have any reinforcement dowels. Few work reinforcement tying, shuttering, and RCC work done for diaphragm beams at end of the girders by onsite level.

Field study 2: Investigation at Road work of ramp RE Wall Panels, Lucknow International Airport

Fig 13: Reinforced Earth Wall panels works lifting and erection work going smoothly because the RCC precast panels are interlocked type there is no steel dowels bars at the joints of every individuals



Fig 13: Precast RE Wall Panel erection

Fig 14: Soil filling and Compaction work doing by every 200mm to 200mm layers after the one set layers of the RE wall panels erected at both sides of the road. After completion of the soil filling and compaction of work then next layer of the RE Wall panels to be erected at 2nd lift. For this work both RE wall panels erection work and soil filling work will done simultaneously. The works of RE Wall panel's erection, & soil filling compaction are to be monitored carefully. Testing of the compacted every earth layers are mandatory



Fig 14: Soil Compaction work

Fig 15: RE Wall panels works Side Elevations, lifting and erection work going on smoothly.

Note: Here is no steel dowels bars at the joints of the every individual panels,



Fig 15: Precast RE Wall Panel erection

Field study 3: Investigation of prefabricated modular sections at various works at Lucknow International Airport

The following works are taken for field study of prefabricated steel structure works:-

1. Chimney Tower, 2. Lift wall tower 3. Passenger boarding platform bridge,
4. Roof Truss & etc. (fig. 16, fig. 17, fig. 18& fig. 19etc.)



Fig 16: Chimney Tower

Chimney Tower (Fig.16); prefabricated modular section made at offsite location and it was erected by crane. Here the modular section is fixed by using of bolts and nuts at the base foundation



Fig 17: Lift Wall Tower

Lifts Tower (Fig.17); Steel prefabricated modular section erected at site. The modular section was connected with bolts and nuts at base foundation



Fig 18: Passenger Boarding Platform Bridge

Passengers Way Bridge (fig.18) prefabricated steel modular section erected at site. The steel prefabricated modular sections lifted by using crane and erected on location, it was fixed with RCC beams of permanent structures of the buildings by bolts and nuts



Fig 19: Roof Truss

Roof truss modular Sections (Fig.19) it was prefabricated at yards by various individual numbers of the modular sections according to crane lifting capacity and working space. The individual modular sections are lifted and erected on locations of roof; the modular are connected together one with another by bolts and nuts.

Suggestion: Opportunities of Offsite Construction by Different Modes

- a) From page No: 10 &11 for elevated road works, the precast RCC girders are erected on the position on pedestal smoothly by using the crane. Here works are during the erection by lifting machineries using cranes there is no barriers identified, because there were no reinforcement laps/dowels are coming at the joinery portions of the members with exist base of RCC surface.
- b) From page No: 11 & 12, the RCC precast RE wall panels are during the erection by lifting machineries using cranes there is no barriers identified, because there were no reinforcement laps/dowels are coming at the joinery portions of the sections.
- c) From page No: 13 & 14, the prefabricated steel modular sections are during the erection by lifting machineries using cranes there is no barriers identified, because the joints of the sections are bolted with nuts immediately, here no reinforcement laps/dowels are coming at the joinery portions of the sections.

Conclusion

1. The entire RCC buildings structure not constructed by individual precast elements due to the factor of Reinforcement steel laps zones of the individual elements, dowels of reinforcement steel bars at every joints of the elements.
2. Prefabricated modular steel section are is old method but we can adopt to all subsidiary works like roof truss, chimneys & etc. RCC Modular precast sections also can possibility to adopt to the typical floors structures like residential, commercial buildings etc.,
3. For multistoried buildings partially we can adopt offsite manufacturing construction system for elements like roof slabs, staircase, cladding etc. except the structure main columns, beams and foundations.
4. For precast elements are we can adopt in Deck slab for elevated roads works, girders for elevated roads works, RE Wall panels at road ramp areas to connect with elevated roads because here the works are not disturbed during the erection of the individual elements by the factors of steel dowels.
5. Initial higher capital cost for offsite construction works due to requirement of lifting Equipment's and formwork.
6. Design is not flexible in case of Offsite construction once adopted.
7. Highly skilled worker required offsite construction works.

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