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ANALYSIS OF PRECAST SUPERSTRUCTURE USED IN MAJOR INFRASTRUCTURE PROJECTS.

(A CASE STUDY OF PUNE METRO)

[1]Mr Swapnil Sawant, [2]Prof. Abhijit. N. Bhirud, [3]Dr. Navnath V. Khadake

[1]PG Student, [2]Assistant Professor, [3]Professor & HOD

[1]M E (Construction management), JSPM's Imperial College of Engineering & Research, Wagholi, Pune, India

[2] JSPM's Imperial College of Engineering & Research, Wagholi, Pune, India

[3] JSPM's Imperial College of Engineering & Research, Wagholi, Pune, India

Abstract: Vehicle population in cities of India is increasing at a fast rate. As result of rapid growth smart solution required for cites infrastructural growth, all of which require to be integrated with public transport. Various researches and development are held by researchers to find economic and time saving technic of constructions. Precast concrete is one of those researches. The favor of precast method in construction has increased worldwide in the last few decades. This method of superstructure casting in metro projects offer multiple advantages to owners like reduced costs, reduced construction time, reduced environmental impacts, and reduced maintenance of traffic. Infrastructure projects like Metro, flyover alignments are fixed and constructed in high dense traffic areas where diversion of road either costly or not possible. With precast we can solve traffic diversion or road block issues while construction of any infrastructure project. The construction of both medium and long span precast concrete segmental spans is widely spread throughout India for metro projects. This method can also be taken in highways, railways, and rapid transit, in both urban and rural area. Alignment can be straight or curved, and can implement in long spans for difficult obstructions and territory. This paper reflects the various types of precast superstructure. Also from the points of cost, time and safety, this paper contributes to promote the use of high performance concrete, and to optimize the design and the casting of precast segmental spans, especially precast viaducts built by precast segmental method.

***Keywords*- Precast Concrete, Alignment, precast viaducts, metro, rapid transit**

I. INTRODUCTION

The conventional cast in situ method of infrastructure is used in the majority of construction projects in India; however, there is still a significant demand for Infrastructure. As a result, construction must proceed at a considerably faster pace. Precast concrete has been around since the Romans invented it. Precast has a lot of potential in infrastructure. However, cities are densely inhabited, and traffic is expanding daily. Precast is the best suitable alternative, since it does not restrict the traffic flow with development taking place at a faster rate. Precast must thus be encouraged in infrastructure tenders. Precast meets needs for subsurface services, subways, tunnels, highways, pavements, flyovers, etc. as the country moves towards smart cities. Even now, conventional construction methods are very uneconomical as compared to precast technic. Precast Construction standardizes on-site and off-site construction methods and work procedures. Precast Construction allows for efficient control of cost and time. Precast construction reduces the demand for construction labor, cost and time overruns, site hazards, time consumption, and resource wasting. In infrastructure projects, the benefits of precast are unparalleled, such as superior quality due to controlled environment, shorter project duration, less material waste, standardisation of methodologies, effective pre-engineering using BIM software to model the structure at element level, and reduced on-site activities. Precast technology in urban and related infrastructure domains such as culverts, bridges, and pipe lines can lead to faster, neater construction with fewer site labour, better site control, accuracy, and quality finish. Precast technique in bridges and flyovers is widely used globally, and India has adopted it in the structure of segmental bridges, culverts, deck slabs, and segments for metro viaducts.

1.1 Objectives:

1) To study the different types of Precast Superstructure in infrastructure projects.
2) To compare cast in situ and precast superstructures used in infrastructure projects.
3) To examine the feasibility of Precast Super Structure in actual case study (Pune Metro) in consideration of time.
4) To evaluate the feasibility of Precast Super Structure in actual case study (Pune Metro) in consideration of Cost.

II. LITERATURE REVIEW

There are lots of literatures available regarding various methods of precast structures used in construction industry. This study takes reference of the above-mentioned category of works to extract a framework for research.

2.1 Nagaraju Kaja, Anupam Jauswal,"Review of Precast Concrete Technology in India". International Journal of Engineering Research & Technology (IJERT) Volume 10 Issue 6, June-2021. Multiple technical analysis show that Indian construction industry has adopted the use of precast technology is only 2% (approx.) of the total. Presently the use of precast concrete construction (PCC) method is restricted to infrastructure projects like Metro, Monorail, Bridges, etc. This research paper studied the various methods and elements of precast concrete technology. This paper also considers the various factors should be taken care of to increase the adaptation of PCC technology in the Indian construction industry. This research suggests that to achieve a high quality with less use of resources like cost and time during the construction of precast structures. [3]

2.2 Baoxi Song, Dongsheng Du, Weiwei Li "Analytical Investigation of the Differences between Cast-In-Situ and Precast Beam-Column Connections under Seismic Actions" Science Direct 22 November 2020 The response differences between precast frames and the RC frame were significant, to reveal the differences between precast frames and the RC frame in terms of structural capacity curve, displacement response, ductility demands of components and structural residual deformation showed that under strong seismic excitation, so it is useful to establish nonlinear models suitable for precast frames in seismic analysis. This study is important for understanding and differentiates the nonlinear response of precast frames and traditional RC frame. [4]

2.3 Azim Mohd Radzi, Roszilah Hamid "A Review of Precast Concrete Subjected to Severe Fire Conditions" Research Article 30 November 2020 Article ID 8831120. Most of the studies are focused on the impact of exposure of rigid concrete beam-to-column connections to high temperatures. This paper is a thorough review of the literature on the performance of precast concrete beam-to-column connections under fire conditions. This paper studies primarily on the case studies of real fires, large-scale fire tests, computer simulations and analytical models, fire resistance tests on the connection elements, and assessment and rehabilitation of fire-damaged precast concrete. (E paper also discusses the current issues and possible challenges). [5]

2.4 Shubham D. Auti1, Dr. Jalindar R. Patil," Prefabrication Technology - A Promising Alternative in Construction Industry" International Journal of Science and Research (IJSR) Volume 8 Issue 8, August 2019. Prefabricated building pieces are constructed in a warehouse and then delivered to the site for final erection and installation, reducing waste. So both time and money are saved. According to the report, prefabricated buildings are much less expensive and take less time to cast than traditional buildings. Prefabrication reduces negative environmental repercussions and provides an eco-friendly structure. Prefabrication is thus more efficient and sustainable. This technique can improve quality control for repetitive tasks. The author concludes that while prefab technology is cheaper than traditional cast in place, there are several factors to consider when utilizing it. Social, economic, and environmental sustainability may support prefab technology as a good option in construction. [6]

2.5 Ashish Wanve , Gaurank Patil, Constructability & Cost Feasibility Analysis of Pune Metro Rail Project Including Planning & Design Specifications" International Journal of Innovative Research in Science, Engineering and Technology. Vol. 8 Issue 2, November 2019. The author points out that the current street-based urban transport system in Pune is under strain, causing longer travel times, increased air pollution, and an increase in street accidents. With an estimated increase in the city's population, upgrading and expanding transportation infrastructure is vital. A rail-based Metro system in the city has been suggested. With regards to the project's environmental impacts, the project has a few beneficial benefits (especially because of the project's usage duration) for which an Environmental Management Plan has been created. Written in after assessing the various options for executing the Pune Metro Project, it was decided to execute it via an SPV funded by DMRC. According to research, the passage construction was assessed based on Delhi Metro tolls decided by the charge obsession committee in 2009, and adjusted for 2018. To analyze the task's return, the tolls have been updated every second year by 12%. [7]

2.6 Jasim Anamangadan, J. Visuvasam, Anoj Kumar Dubey, Comparative Study on Various Behaviours of an RC Structure with Pre-stressed Concrete Structure, Research Gate, January 2019. This paper discusses the various structural behavior of a multi-storied RC Convention Centre building having large spans of around 32 m. The effect on the structure due to these large spans is compared with both RC and pre-stressed concrete. With use of software Adapt Builder 2016 the roof slab of the auditorium portion of the structure is designed with normal RCC and compared with Slabs resting on Pre-stressed Post-tensioned Girders. A comparative reserch between RCC and pre-stressed concrete is also done. For seismic design diaphragm action of the structure is considered in order to provide a monolithic action and hence to counteract the effect of torsion. A relative study is done with and without considering the effect of torsion into account and the results shows that in higher seismic zones the effect of torsion is predominant and proper care should be given to extreme columns and corner columns which are more vulnerable to failure. Response spectrum analysis of the structure is done in STAAD.Pro and storey response plots are obtained. [8]

2.7 Vakas K. Rahman, prof. A.R.Mundhada," Comparative study of RCC and pre-stressed concrete flab slab" (IJMER) Volume 9 Issue 4, May 2019 This paper presents the difference of R.C.C. and Pre-stressed Concrete Flat Slab. This work includes the design and estimates for R.C.C. and Pre-stressed Concrete flat slabs of various spans. The aims of this work are to design R.C.C. as well as pre-stressed concrete flat slabs for various spans and then compare the results. A Microsoft excel programing is done to design both types of flat slabs. The purpose is to reach a definite conclusion regarding the superiority of the two techniques over one another. Results shows a R.C.C. flat slab is less costly than pre-stressed concrete flat slab for smaller spans but vice versa is true for larger spans. [9]

2.8 Zhiwu Yu, Xiaoyong Lv, Yujie Yu "Seismic Performance of Precast Concrete Columns with Improved U-type Reinforcement Ferrule Connections" International Journal of Concrete Structures and Materials, Springer 2019, Article no 54. This paper shows that PC columns with welded URF connections can ensure better lateral resistance than the cast-in-place concrete column. The weld type and length affects the connection performance and the 15d-welded and full-length welded URF connections presented good connection performance and same was recommended for the assembly of PC columns. Then, study on finite element was performed to further reveal the working and failure mechanisms and the affecting mechanism of some working parameters. Parametric simulations shows that the increase in the axial load ratio and the concrete strength in the post cast region had a slight but less effect on increasing the lateral resistance of the column connection. [11]

2.9 Umamaheswara RaoTallapalem, et.al "Time History Analysis on Precast Building Connections", International Journal of Recent Technology and Engineering (IJRTE) Volume 8 Issue 4, November 2019. This study shows in G+20 High rise building there are three types of Beam-columns connections such as Rigid connection ,semi-Rigid connection and Hinged connections are developed. With help of Time history analysis of High Seismic waves, Moderate Seismic waves and Low seismic waves these High rise building was analyzed. The results of Top Displacements , story Drifts and Inter story Drifts are compared for the Different connections and Different Seismic waves.[12]

2.10 K. Shanmuga Sundaram, "Hyderabad Metro Rail Viaducts Precast Segmented Balanced Cantilever Method of Launching of Segments by using LG & OH Gantry at ROB", Volume 5 Issue 6, 2018. For the red, green, and blue lines viaducts, this article presents the pre-cast segmented Balanced Cantilever Method of launching segments employing LG and OH Gantry at ROBs. Precast segments with balanced cantilever erection were used, combining the speed of construction of precast segments with the balanced cantilever method (longer spans). It is a versatile technique for today's rapid track jobs. Segments can be thrown away from the actual site, reducing traffic and public inconvenience. Casting yard can control quality and dimensional tolerances better. Segment casting can begin independently of foundation work, speeding up overall completion. [15]

2.11 Anand Kanade "Study Of Structural Analysis of PSC Box Girder Viaduct for Pune Metro" International Journal of Research in Engineering and Technology Volume: 07 Issue: 11 | Nov-2018. The paper finds that the most cheaply and safe section can be attained by taking trials quickly. This atomization is ideal for all design offices. This choice of segmental box girder is cheaper than traditional precast girders. A bridge's size influences the involvement of various loads and hence its design. When designing any metro railway bridge, the design basis reports must be strictly observed. [18]

III. RESEARCH METHODOLOGY

3.1 Problem Statement

"As metro cities' infrastructure work increases significantly. However, due to land scarcity and traffic congestion in metro areas, precast construction is essential. The precast Super Structure is one of the greatest options achieve quality requirement, affordability, and time. Now a day construction industry needs to be industrialized to achieve production time and finishing of structure. Construction industry requires ecofriendly techniques to avoid pollutions caused while constructions which can be considerably controlled in precast casting yard where construction activities are running in designated area likely outside of cities."

3.2 Methodology

This research was done to study the different types of precast superstructure used in Infrastructure projects and also to analyze the feasibility of precast superstructure's in viaducts metro projects. Conducted general review of construction industry and literature review to investigate the present scenario of precast superstructure in Infrastructure project. A study was conducted by physical visit to Pune Metro rail project reach-01. After reviewing various types of spans, one standard span length of 28 M was considered for feasibility study. Analyzed theoretical and practical quantity of data required to cast one particular span using precast segmental method. By using approved drawings various material quantities such as reinforcements (diameter wise) for different cross sections of spans, concrete quantity of individual segment, shuttering quantity for different sections are calculated. Then analysis of site data for precast Super Structure in actual case study (Pune Metro) with consideration of time, obtained from actual time cycle analysis for particular span are evaluated. Different activity time cycles (actual and theoretical) of segment casting in casting yard such as time required for reinforcement cage binding or time required for cable profiling etc. are calculated. Also for launching by span by span method according to different activities time cycle are evaluated. Analysis of site data using PSM method in consideration of cost, obtained from actual cost analysis for particular span.

IV. DATA COLLECTION & ANALYSIS

The data was collected by reviewing various literatures from research journal, online websites, project records, manual and news from internet. The data was collected from viaduct portion of reach-1(Purple line) starting from Pimpari chinchwad Municipal Corporation to Rang hills which have precast segmental superstructure and some spans of composite girders. This report studies the precast superstructure of standard spans of 28 M straight. Actual site data of standard span was collected and analyzed with consideration of time and cost required to cast one particular segment and to cast one full span with precast segmental method. Also analysis of time and cost required for launching of precast structure using span by span method.

4.1 Types of precast superstructure:

Twin U-Girders: The twin U-Girder viaducts are structure which can have one girder for each track. This method is popular because it is one of the quick construction techniques. However, feasibility of this method dependent on the ease of transportation and erection of the girders.

I Girders: I-Girders often have an I-shape cross section consist of two load-bearing flanges separated by a stabilizing web. The feasibility of this type of superstructure depends on transportation of casted girder. There may be number I shaped girders in one span depend on deck width of project.

T Girders: The top of T shape cross section act as flange in this type of girder. These types of girders are used in small span lengths like in station area. Again selection of this type is mainly depending on feasibility of transportation and loading criteria.

Precast Segmental box girders: This is most common method used now days in large infrastructure projects. It serves many benefits in terms of time, cost and ease of transportation from casting yard to reception site. One span is divided in to numbers pieces called segments which can be stacked separately and transported on site individually.

Balance Cantilever: This type of superstructure is used for special purpose span like crossing important road junctions, railway spans or large water body etc. This method is highly suitable for cable stayed bridge. Idea of balanced cantilever construction method is to erect the segments in an alternate manner at opposite ends of cantilevers which are supported by piers.

4.2 Time Cycle Analysis:

The following figure shows the time cycle for one entire straight span of 28 m length. The following considerations have been taken to give appropriate relationship to each segment as observed on site:

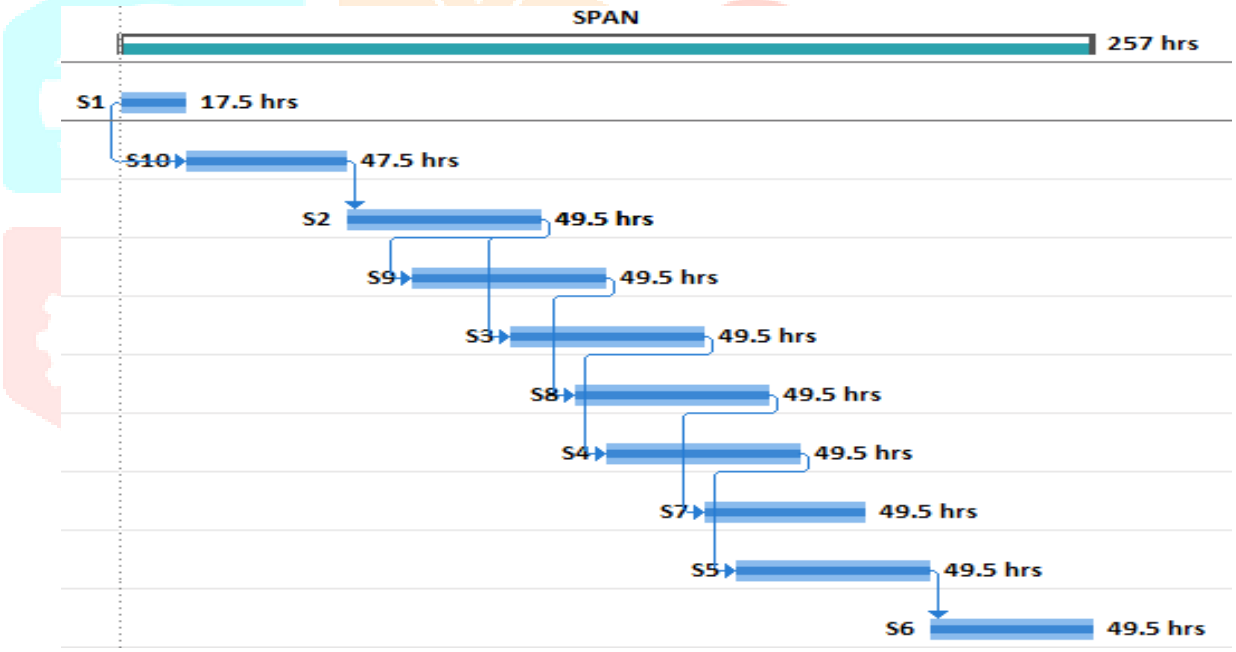

Figure 1- Time cycle for span casting

The sequence of construction is: S1, S10, S2, S9, S3, S8, S4, S7, S5 and S6.
Time cycle of end segment S1 is considered from cage preparation to concreting i-e 17.5 hrs. While for end segment S10, time cycle is considered from reinforcement fixing to de shuttering. Because after de shuttering of end segment only, they are lifted from short beds to long line bed and then only the next normal segment can be concreted by match casting.
Cutting and bending doesn't depend on any other activity so no relationship is required.
As per the sequence, after concreting of the previous segment, cage preparation for next segment in sequence is started. So the relationship is given accordingly. For the last segment S6, S6 concreting can be commenced only after the de shuttering of Segment S5. Hence the relationship is given accordingly.

4.3 Cost Analysis:

The Bellow table shows the cost analysis for one entire straight span of 28 m length. The following considerations have been taken to give appropriate relationship to each segment.

Table no. 1- Cost Analysis of Span

ITEM NO.	PARTICULAR	UOM	UNIT COST	QUANTITY	TOTAL COST	COST DIVISION (INR)				
			INR/UOM		INR	MATERIAL COST	LABOUR COST	TEP COST	WATER	PROFIT AND OVERHEADS
1	Segment reinforcement	MT	53328.83	21.65	1154569	899916	40785.75	63271.4	0	150596
2	Segment formwork	m2	666.35	674.12	449198.3	245508.4	26787	116928.8	0	65268.13
3	Segment concreting	m3	5217.81	151.42	790081.2	577369.5	5880	97945.17	5832.49	103054.1
4	Segment lifting	no.	966.61	10	9666.09	0	852.5	7409.11	0	1404.47
TOTAL COST FOR ONE 28m STRAIGHT SPAN (INR)					2403514.7	1722793.9	74305.25	285554.5	5832.49	320322.6
TOTAL COST FOR ONE SEGMENT (INR/SEGMENT)					240351.47	172279.39	7430.53	28555.45	583.25	32032.26

The above table shows total cost for casting of one span (28M span) is around 2.4 lacks including all overheads.

VI. CONCLUSION

The precast concrete technology has already started growing in infrastructure projects in India due to its need of quality requirement, construction speed and reduced work force. This paper was aimed to aware precast technology as a fair substitute in Infrastructure projects.

The paper represents the study of different types of precast superstructure used currently in large infrastructure projects. It reflects feasibility of different type of precast superstructure techniques used in Indian Metro construction projects. Precast segmental method for superstructure is most feasible technique in consideration of transportation and launching which is one of the most critical activities in precast superstructures.

Based on case study carried out on actual site, data shows one precast segmental span can be casted in total 257 hours i.e. approximately 13days required to cast one full span considering day and night shifts. With total 5 no's casting beds in casting yard, 5 no's of spans can be completed in 13 days. Hence precast superstructures are more feasible than conventional method superstructures in consideration of Time. Also study reflects cost required to cast individual segment and for one full span 28M length including all overheads which is which is more affordable than conventional superstructure casting. Which conclude precast superstructure casting is more feasible than other technique in consideration of Cost.

If precast technique is used over conventional technique in India it can be very useful and advantageous to solve many issues . Maximum number of structures with greater quality and in minimum time can be provided by using precast technique than using conventional technique.

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