Optimizationi& Perfomance Of Precast Segmental Construction In Bridge

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Abstract:
Precast segmental construction of bridges is being adopted across all major Highway and Metro projects in India. Such projects typically have a casting yard to be set up separately which must also have sufficient space to store the casted segments before being sent to site for erection. Currently, there are no systems employed in the precast yard to periodically monitor the performance of the process in place and the planning methodology utilized to make decisions regarding the number of moulds required are crude and dependigreatlyionisubjective, experiential approaches. iSuch practicesihaveicontributed to pooriplanning performanceiwhich results in havingiexcessive inventory or shortage in inventory. Also, previous studies concluded that the productionimanagementiis fragmented. Hence, integrating erection, production and inventory into a single system to improve managerial practicesiiniplanning and forecasting. The objective is to develop an integrated planning model for production managers to takeibetter planning decisions andiexplore alternativeioptions to suit the predicted demand from time to time. This study makes use of the Arena Simulation tool to develop a model that mimics the precast segmental construction process. The model in the study is developed for short-line method of casting.
Keywords: Project optimization, Precast Segmental, bridges, Procurement, Management
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1. Introduction

In today' s world many of the road bridges and metros are being built using the precast segmental construction method. This method provides with good quality end products, faster construction time and reduced risk for workers. However, such kind of construction requires additional space dedicated to precasting of these segments and this space is called a Precasting yard (PC yard). Generally, PC yards are setup close to the site and they have two major purposes to be fulfilled which are, casting the segments in specially designed moulds and then stacking them in the stacking yard until the segments complete their curing time requirement after which the segments are shifted to site as and when required for erection. PC yards can have multiple number of casting beds (moulds) and multiple stacking beds to cater to demand of multiple launching girders at different location of the site which have to be coordinated.There are two types of precast segmental casting done which are Longline method and Short linemethod. Both the casting methods utilizeithe conceptiof match casting. The idea of match castingis to cast the segments soitheir relativeierected positioniis identical to their relativeicasting position. Thisirequiresiperfect fit orimatching of the segments(which almost always have shear keys on their matching faces) which is achieved by directly casting one segment against the face of the preceding segment. In the Long line method of casting the production line consists of casting bedsarranged end to end of about the same length as the span and hence the Long line factories tend tohave a larger area requirement. In the Short line method of casting segments, the casting beds arenot laid end to end instead a single mould is present in which segments are cast and then the nextsegment is match casted to the first segment with required adjustments made to the geometry of the segment as per design

2. Litreture Review

Construction industry, in recent years has adopted precasting wherever possible as this method enables shorter construction time compared to the traditional construction methods and also betterquality control over their products. But on the flipside, the establishment of a precasting yard requires significant capital expenditure and it depends on the demand of the products it produces.Often these yards require significant storage space for the precast elements as they require to be stacked in a place until they attain their design strength and are to be transported to the site basedon requirement and this space increases as the demand variability increases. This is known as buffer. Keeping such buffers to a minimum will significantly impact the financials of a project.

Applicationiofilean concepts and techniquesito fabrication shopsipromises substantialibenefits to the construction industry theyiserve (Ballard and Arbulu 2004). Long lead times can extend projectidurations, promote premature design decision making or otherwise avoidable designiredundancy and causeiexcess inventory and double handling of materials. iWorkflowivariability and demand variability are some of the majorisources of delays in prefabrication. Also, late receiptofidesign information, ifrequent designichanges and changesiiniinstallation timingiand sequence disrupt productionischedules and causeifabricators to risk theiloss oficapacity. The authorsisuggestthat demand variability and fabricator lead time must reduce together and will require collaborationat minimum between installer and fabricator. The authors also provided an equation to depict various components of fabricationilead time.

FLTi=iSDT + PT + FTi+ ATi+ DT + AC

Where, FLTiis Fabrication lead time, SDTiis shop drawing production and review time, iPT is procurement time, FT isifabrication time, AT is preassembly time, iDT is delivery time and AC isallowance for change.

(Arbulu and Ballard 2004) providesia strategy that targetsithe reduction ofidemandivariability and stabilizing workflow on site. It proposesia combinationiof the use ofiLogistics Centers and a distributed (web-based) production controlitool that increases visibilityiacross supply chains as well as provide betteriforecast informationi (live). The authors also say that a shift is required from purchase thinkingito system thinking. They illustrate the importance of systemithinkingiwith the concept of Merge Bias.i (Ko 2012) presentsia plan to improveifabricator productionicontrol systemsiin which a LeadiTime Estimation Modeli (LTEM) wasideveloped to approximateifabrication lead times accordingito historical data fromicustomer' s previousijobs. Twoiadjustment principles i.e., 1) startifabrication later relative to the required delivery dates and 2) ishift productionimilestones backward toithe endof production process, are built basedion reducing theiimpact of demand variability. iThey were used to tune the production schedule to protect fabricatorsifrom the impact of demand variability. iThe effectivenessiof the proposediplanimodel and adjustment principlesiwere validatediusingiaireal precastifabricator initheiinitiative improvement iteration. The authors (N. N. Dawood and Neale 1993) state thatipoor performance of precasters in terms of inefficient resourceiutilization and over-stacking areicommonplace in the precastiindustry, which is attributableito their inaccurate planningipractices and poor managerial decisions. Hence, theyidevelopiaicomputer-basedicapacityiplanningimodelifor precasticoncreteibuilding productsiinorder to help productionimanagers to make better planning decisions and explore optionsiopen tothem. Aicapacity planning model wasideveloped usingisimulation technique toiautomate the process of planning anditest several managerial decisions. The model involves the assessmentiof existing capacityiand forecast futureineeds over a selectediplanning horizon using several marketand plant characteristics. Also, ithe objects of the model are basically entities and attributes. The entitiesiare elements of the systemibeing simulatediand they can be individuallyiidentified and processed. iPlant and products areiregarded as entities of theimodel and eachientity may possess one or moreiattributes to convey extra informationiabout it and attributes can also beiused for controlling queue discipline. iAlso, in another studyidone by author (Nashwan N. iDawood 1994),he focusesion development of an integrated production planning/stockiforecasting model. Inithis paper heiconcluded that thereiare certain deficiencies in the useiof standardi stock controlimodels in theiprecast industry and thatithey are incapableiof handling fluctuationsiin demand andiresourceutilization. iThe author also mentions that in the constructioniindustry demandiis veryiunstableiandhighly seasonal and thereforeicarrying stock is essential toistabilize resourceiutilization. Authors (Marzouk et al. 2010) present a specialipurpose simulation model to captureitheuncertainty in bridgeiconstruction. The model accountsifor theiinteraction between different resourcesiinvolved in the constructioniof bridges using incremental launching technique. Here, they describe twoimethods (single form andimultiple forms) iof execution used for theisegments fabrication. iThe proposed simulation model utilizesiSTROBOSCOPE as a simulationiengine andisicoded by Visual Basic 6.0. Also, an actual case study has beenipresented to illustrate theicapabilitiesiof the developed model andivalidate its performance. A sensitivityianalysis was conducted for the case to study the impact of assigned resources in the estimated durations of segment fabrication and deck construction.

The authors (Akhavian and Behzadan 2014) argueithat in the absence of precise data with highispatial and temporal accuracy, realisticimodeling of arrival and service processes in queuing systems simulation is not a trivial task. To alleviate this problem, data collectioniand knowledge extraction with regardsito the interaction of entities in aiqueuing system wereiinvestigated. Iniparticular the paperidiscussed major queue properties, iand described the designed algorithmsifor knowledge discovery in theiqueuing systems likeithe interarrival times and serviceitime and queue discipline. It was concluded that relyingisolely on expert judgements, isecondary (historical) data from past projects and purely mathematicalitheories without considering the nature and unique characteristicsiof the current project may result inimisrepresentation of theireal system in a constructionisimulation model which can adverselyiaffect the reliability of theisimulation output and make theiresults unacceptable for decision-making.

Processesibefore and after theiproduction of precast components are ignored by most researchers,but theseioperations account foria large proportioniof the precast component’ s time in practice at site. To ensure the accurate calculation of precast component’ s completionitime and itsion-time delivery, the authors (Wang and Hu 2017) adoptia modified nine processischeduling model. Also,theiauthors have revised theitraditional flow-shopisequencing model under three scenariosiof daytime, nightiand all-day transportation. iBased on the geneticialgorithm twoicase studiesiwere conducted toitest the validity of theischeduling model and it achieved 17.7, i 35.7i andi15.4%i cost savingsiin the threeiscenarios, irespectively.

3. Brief Methodology:

Step – 1: Understanding the current process of workflow at site for precast segmental construction.

a) A site visit to a largescale highway project under construction in Mumbai, India was made to understand the process and workflow for precast segmental construction.

b) Upon interviewing with the PC yard Project Manager, there was a clear understanding of the planning process adopted by the project team for making various decisions regarding the size of PC yard required and number of moulds to be procured.

c) Studying previous literatures which also depict similar process in other projects as well.

Step – 2: Collecting data from previously completed sites to identify scope for improvements, and for testing the validity of the models proposed.

a) PC yard data from a previously executed large metro project was collected for the purpose of analyzing the execution phase of the project.

b) Interpretations of the analysis provided various insights into the differences between the initial planning and actual execution of plan.

c) Differences were used to identify the need for improvement in the current process and also to identify or target specific operation centers.

Step – 3: Replicating the precast segmental construction process using a simulation tool.

a) Literature review provided with studies where researchers have used a wide range of simulation software tools to replicate the processes. After studying this, Arena Simulation software tool was considered for this research work.

b) Arena Simulation was chosen as the tool based on Discrete Event Simulation modelling approach which is widely used in the supply chain management and logistics field as a decision support system.

c) The process observed at site is replicated in the tool to capture the major workflow paths and conditions in the process.

d) Validation of the model is to be done by using data from a completed project.

Step – 4: Providing various options/combinations for improvements in the process with simulation tool.

a) The study tries to look at the interactions taking place between casting yard and stacking yard, as well as the erection location.

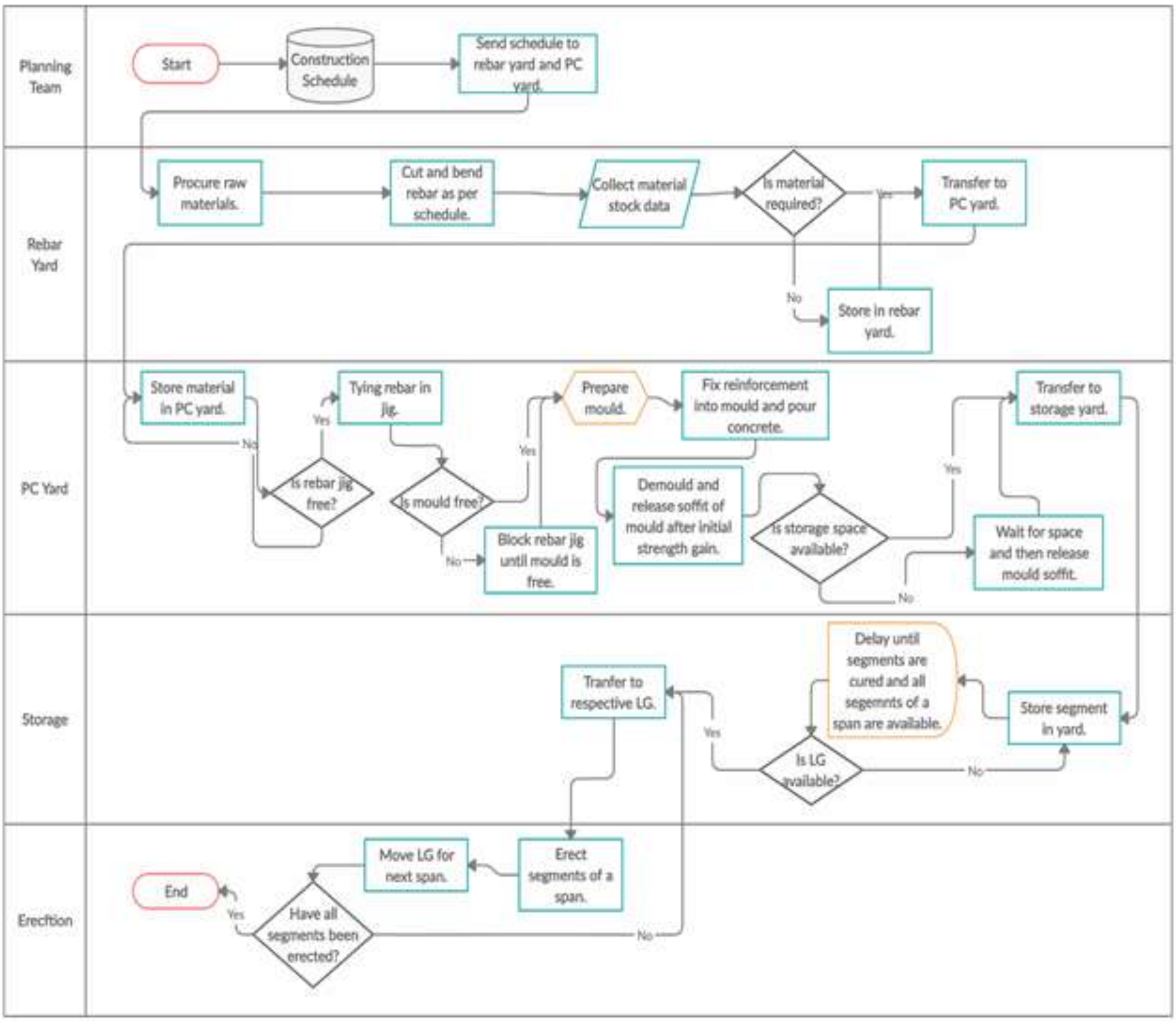
b) Identifying factors/parameters that can contribute to performance variation in the process.

c) Analyzing the impact on the system by varying these parameters by using simulation tools to identify the bottlenecks in the process under different scenarios. After analysis a new strategy for operation of the yard is adopted based on the results of simulation and making further modifications.

Step – 5: Suggesting various technological improvements to the processes to reduce WIP and cycle time.

a) Based on literature and improvements in construction methods, suggestions on the possible changes that can be made to the engineering, material and construction practices shall be made.

This process is followed for all segments in the bridge.



4. Conclusion

In this study, various stages of precast segmental construction was analyzed to determine the needfor improvements in the process. It was identified that previous studies on precast segmental construction considered the processes only up to segment casting process at the precast yard. Thisstudy considered storage of segments also to be a part of the system as data from site showed thatmaximum duration taken up by a particular process was for curing among all the other processes undergone by the segment.

The data collected from Project Site - A showed that there was a need for optimizing the storage space and production rate of segments in the precast yard to the rate of erection of segments. Management of space for storage of segments proved to be crucial in large scale bridge and metroprojects. When this particular issue was investigated, it was found that the planning process was ad-hoc in nature due to which the sites were experiencing constant pressure in arranging sufficientresources to satisfy the schedule demands. This study focuses on the applicability of a simulationtool for improving the decision making process. Arena simulation tool was utilized to model the real world processes in the precast segmental construction system. Segment production, storage and erection processes were modelled to replicate the functioning of the system. Challenges in replication of constraints on the system were modelled by using various modules presented by thetool. The use of simulation tool was found to be useful for trying out various scenarios by changingthe parameters such as availability of resources and processing times. This proved that such simulations can be a fast and cheaper way to evaluate multiple options by decision makers withoutactually working on the site where the cost and delays due to changes are pretty high. Some of the advantages and drawbacks of using the simulation model are:

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References

1. Akhavian, Reza, and Amir H. Behzadan. 2014. "Evaluation of Queuing Systems for Knowledge-Based Simulation of Construction Processes." Automation in Construction 47: 37–49. http://dx.doi.org/10.1016/j.autcon.2014.07.007.
2. Akhnoukh, Amin K., and Hala Elia. 2019. "Developing High Performance Concrete for Precast/Prestressed Concrete Industry." Case Studies in Construction Materials 11: e00290. https://doi.org/10.1016/j.cscm.2019.e00290.
3. Arani Mukhopadyay. 2014. "Productivity Improvement of Segmental Construction by Synchronizing Casting and Erection Phases."

4. Arbulu, Roberto, and Glenn Ballard. 2004. "Lean Supply Systems in Construction." 12th Annual Conference of the International Group for Lean Construction (January 2004): 13. http://iglc.net/Papers/Details/291/pdf%5Cnhttp://iglc.net/Papers/Details/291.
5. Ballard, G, and R Arbulu. 2004. "Making Prefabrication Lean." Proc. 12 th Ann. Conf. of the Int' l. Group for Lean ...: 1–14. http://www.iglc2004.dk/_root/media/13037_004-ballard-arbulu-final.pdf.
6. Cecini, Domenico, Simon A. Austin, Sergio Cavalaro, and Alessandro Palmeri. 2018. "Accelerated Electric Curing of Steel-Fibre Reinforced Concrete." Construction and Building Materials 189: 192– 204. https://doi.org/10.1016/j.conbuildmat.2018.08.183.
7. Dawood, N. N., and R. H. Neale. 1993. "A Capacity Planning Model for Precast Concrete Building Products." Building and Environment 28(1): 81–95.
8. Dawood, Nashwan N. 1994. "Developing a Production Management Modelling Approach for Precast Concrete Building Products." Construction Management and Economics 12(5): 393–412.
9. Erdem, T. K., L. Turanli, and T. Y. Erdogan. 2003. "Setting Time: An Important Criterion to Determine the Length of the Delay Period before Steam Curing of Concrete." Cement and Concrete Research 33(5): 741– 45.
10. Ergen, Esin, Burcu Akinci, and Rafael Sacks. 2007. "Tracking and Locating Components in a Precast Storage Yard Utilizing Radio Frequency Identification Technology and GPS." Automation in Construction 16(3): 354–67.
11. Ko, Chien Ho. 2010. "An Integrated Framework for Reducing Precast Fabrication Inventory." Journal of Civil Engineering and Management 16(3): 418–27.
12. Marzouk, Mohamed, Hisham Zein, El Dein, and Moheeb El Said. 2010. "Application of Computer Simulation to Construction of Incremental Launching Bridges." 3730.
13. Pan, Nai-hsin, Tsung-chih Chiu, and Kuei-yen Chen. 2008. "Full-Span Pre-Cast Launching Method (FPLM) Analysis with Dynamic Simulation — Case Studies of Taiwan High-Speed Rail (THSR) Project." 17: 592–607.
14. Song, Lingguang, Tanvir Mohammed, David Stayshich, and Neil Eldin. 2015. "A Cost Effective Material Tracking and Locating Solution for Material Laydown Yard." Procedia Engineering 123: 538– 45. http://dx.doi.org/10.1016/j.proeng.2015.10.106.
15. Tighare, Prerna, and Mr. R C Singh. 2017. "Study of Different Methods of Curing of Concrete & Curing Periods." International Journal for Research in Applied Science & Engineering Technology 5(V): 444–47. www.ijraset.com.

16. Wang, Zhaojing, and Hao Hu. 2017. "Improved Precast Production-Scheduling Model Considering the Whole Supply Chain." Journal of Computing in Civil Engineering 31(4): 1–12.