

Lecture Notes in Civil Engineering

Anil Kashyap · N. Raghavan ·
Indrasen Singh ·
Venkatesan Renganaidu ·
Arun Chandramohan *Editors*

Sustainable Lean Construction

Select Proceedings of ILCC 2022

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*Dedicated to all Lean Construction
Enthusiast*

Preface

Infrastructure projects play a crucial role in driving economic growth and development in India. The country has witnessed a significant focus on infrastructure development in the past two decades, and the trend is expected to continue in future. However, according to the Ministry of Statistics and Programme Implementation (MOSPI), time and cost overruns distressing major infrastructure projects led to financial impact of Rs. 4.5 trillion as of December 2022. This has an impact on both the productivity and the profitability of such projects.

Given this context, it has been found that the successful implementation of Lean principles has benefitted organizations significantly. Further, with the industry moving towards prefabrication and digitization, Lean-integrated digital tools have the potential to manage resources in an optimum manner without compromising on time, cost and quality.

However, there is a need to bring Lean awareness to construction corporates, government contract companies and stakeholders in the academic and research domains. This is because studies have also indicated that only under 10% of Lean implementation initiatives have actually been successful. This success rate can be attributed to two factors—lack of awareness regarding Lean and restricting Lean implementation to tools and techniques. The need of the hour is to recognize that Lean Transformation is more of a methodological, systemic and cultural transformation that can be engendered through interventions at various levels. This was the main objective of the Fifth International Lean Construction Conference (ILCC) hosted by the National Institute of Construction, Management and Research (NICMAR) in collaboration with the Institution for Lean Construction Excellence (ILCE) at its Hyderabad campus from December 13 to 16, 2022.

The overarching theme of the conference was “Sustainable Lean Construction”. While the workshop sessions were focussed on creating the digital and cultural awareness related to Lean Transformation, the invited national and international speakers and panellists engaged with the current trends, issues and possible solutions for Lean Implementation in the construction and infrastructure domains. The technical sessions provided a forum for discussing some cutting-edge Lean research initiatives

in the construction domain. The delegates included owners, contractors, consultants, coaches and academics.

This book comprises some selected research papers from this conference dealing with several topics and research areas which will be beneficial to students, researchers and professionals working in the field of Lean Construction. These include

- Lean Culture and Behaviour
- Lean Health, Safety and Quality
- Leadership and Motivation for Lean Implementation
- Digital Technologies/BIM and Lean
- Automation and Industry 4.0 in Lean
- Lean Design Management
- Lean in Sustainable and Green Technologies
- Lean Supply Chain Management and Offsite Construction
- Lean in Public Sector
- Lean in Contract Management
- Lean Production Planning and Control
- Cost–Benefit/Return on Investment (RoI) of Lean Implementation
- Lean Readiness and Maturity
- Waste and Productivity
- Integrated Lean Project Delivery
- Lean in Modern Construction Techniques
- Teaching Lean and Way Forward.

I thank all authors, co-editors, reviewers, volunteers, faculty and staff of NICMAR Hyderabad, ILCE board members and our sponsors for their support and cooperation during this event. I would also like to thank the team at Springer Nature for publishing the conference proceedings.

Hyderabad, India

Dr. Anil Kashyap
Director General—NICMAR

Acknowledgments

This edition of ILCC 2022 with the theme “Sustainable Lean Construction” has achieved its aim of providing a common platform for the Lean enthusiasts from the Architecture, Engineering, Construction and Facility Management (AEC/FM) disciplines who came forward and discussed and shared their experience with Lean adoption and implementation of Lean techniques in construction projects. Such a strong interface between the industry and academia resulted in a lot of learning along with an overwhelming sense of gratitude. We, the conveners of ILCE 2022, take this opportunity to acknowledge all those who have wholeheartedly supported the successful completion of this mega event.

At the outset, we would like to express our deep gratitude to our Director General, Dr. Anil Kashyap, for motivating us to organize this prestigious conference to us. We are extremely grateful to him for his kind support, constant encouragement and guidance. We would also like to thank the ILCE Board of Directors for involving themselves in a committed manner and rendering their support in all aspects possible for the conference including arranging the major quantum of sponsorship.

We express our gratitude to Mr. Anup Mathew, Chairman and Director, of ILCE for his constant support and for arranging the gold sponsorship from M/s Godrej Constructions. We would also like to thank Mr. Sagar Gandhi, SPCL, for his valuable suggestions and for arranging platinum sponsorship from M/s Shapoorji Pallonji Engineering and Construction. We would also like to express our gratitude to Mr. Devarajan, URC; Mr. Harleen Oberoi, Tata Realty; and Mr. Giridhar Rajagopalan, Afcons, for their support and for arranging the silver sponsorships from URC Construction (co-sponsorship with M/s Tactive Solutions), Tata Realty and Afcons. Our sincere thanks to the bronze sponsors M/s Aparna, Hyderabad, and M/s vConstruct, Pune. Also, our special thanks go to co-sponsors M/s VisiLean, Ahmedabad, and M/s Bexel Manager.

Additionally, we would also like to thank Mr. Sankar Narayanan, L&T; Mr. Debashish Guha, Arcop; and M/s Puneet Narang for their suggestions and immense support. We would also like to acknowledge the support of all the directors with whom we had interacted during this edition of ILCC.

We owe special thanks to ILCE Directors and IIT Madras senior faculties, Prof. N. Raghavan and Prof. Koshy Varghese, for providing valuable guidance and support in identifying key speakers and domains and in structuring the conference. We would like to express our sincere thanks to the ILCE secretary general Mr. Kaezad Karanjawala and the ILCE technical secretary Dr. K. Marimuthu and their team members for their immense support from the beginning especially in making all the necessary arrangements and for making this event very successful.

Our special thanks go to our media partner M/s Construction World, Mumbai, and our publication partner M/s Springer Nature, Singapore. We acknowledge the contribution made by various authors from academia and industry which resulted in fresh thoughts for knowledge exchange and discussion during the conference. We are sincerely grateful to all the reviewers for their time and effort to align with the theme of the conference and improve the quality of the manuscripts.

Our sincere thanks to Lean workshop coaches Dr. Bhargav Dave, VisiLean; Mr. Prasad Sukumaranunni, Beebox; and Dr. V. Pramadha, NICMAR. We are grateful to our industry day speakers Prof. N. Raghavan, IIT Madras; Dr. Rustogi, ILMA; Mr. Sharique Khan, Turner; Mr. Jayadatta V. Lad, Afcons; Mr. Karun Raj Singh Sareen, KPMG; and Mr. Sabarinath C. Nair, SkillVeri. Our sincere thanks go to conference speakers Mr. Naveen Mittal IAS, Government of Telangana; Mr. Ramamoorthy Rajendran, DigitalBuild, Singapore; Col. Dr. Pawan Pandey, Indian Army; Ms. Durga Saripally, vConstruct Pune; Mr. C. Devarajan, URCL; Dr. Glenn Ballard, University of California Berkeley; and IIT Madras faculties Dr. Koshy Varghese and Dr. Ashwin Mahalingam. Our sincere thanks go to panel moderators Dr. Koshy Varghese, IIT Madras; Dr. Venkata Santosh Delhi, IIT Bombay; and Dr. P. Muralidhar, NICMAR. Our special thanks go to panel members Dr. Rustogi, ILMA; Dr. Barghav Dave, VisiLean; Mr. Kalyan Vaidyanathan, Bentley; Mr. Sabarinath C. Nair, SkillVeri; Mr. G. Suresh Kannan, URCL; Mr. Manish Mokal, Afcons; Dr. Deepak Bajaj, Amity; Dr. Shobha Ramalingam, NICMAR; Mr. Jayadatta V. Lad, Afcons; Ms. Ragavi Prabhakaran, URCL; Mr. Yash Saraiya, Turner; Mr. Parijat Naha, TRI; and Prof. Rajasekar, NICMAR. The ILCE coordinators and SPOC members are the backbones of the event. Immense thanks to Mr. Jitendra, Ms. Diamond, Mr. Vinay and Mr. Pandiaraja, Godrej; Mr. Jayadatta and Mr. Manish, Afcons; Mr. Girish, Mr. Aritra and Mr. Parth, SPCL; Mr. Tapas and Mr. Parijat, TRIL; and Ms. Raghavi, Mr. Karthikeyan, Mr. Suresh Kannan URCL and Mr. Suresh Kamal, Umar Belal, L&T, who have extended all their support to the best possible. We appreciate the assistance provided by our NICMAR community organizing this event. Sincere appreciation is extended to Dr. Indrasen Singh, Dean (Academics), for facilitating academic arrangements and providing constant support and encouragement throughout the event. Dr. Seshadri Tirumalla merits our gratitude for coordinating the infrastructure and support facilities on campus. Dr. R. Sathish Kumar and Dr. V. Srihari, we appreciate your assistance in organizing and coordinating the students for the numerous events of the conference, as well as your support since the conference's inception. Dr. Mahesh Balasubramani, Dr. B. Ravinder and Dr. P. Muralidhar, thank you for being accommodating and scheduling the classes accordingly.

Dr. Savitha Chilakamarri and Professor Raja Sekhar Mamillapalli are deserving of our appreciation for sharing their expertise and contributing to the souvenir. Regarding Logistics, I would like to commend the web team, led by Dr. Kedar Phadke and comprised of Mr. Sandeep Daware and Mr. Amit U. Bartakke, who gave the event a wonderful start and supported us throughout the proceedings. Dr. Amit Hedau and Prof. Saurabh Jindal deserve special recognition for their efforts to decorate and illumine the campus.

We are indebted to the technical committee, led by Dr. Mahesh Balasubramani and comprising of Dr. Vinay Agrawal, Prof. K. V. Prasad, Prof. Vijeyata Malla and Prof. Prashant Kumar Sreram, for coordinating the reviewing and categorization of papers and posters into various themes for scheduling the presentations. We thank Dr. Subash Rastogi, Dr. V. Aneetha, Dr. Mahesh Gangadhar, Dr. Abhay Tawalare, Dr. Deepak Bajaj, Dr. Ganesh Devkar, Dr. Shobha Ramalingam, Dr. Nilesh Patil and Prof. K. Ravindranath Chowdary.

This event would not have been possible without the immense and unwavering support of our faculty colleagues who worked assiduously to ensure its resounding success. We thank Dr. R. Sathish Kumar, Dr. Hanumanth Rao, Dr. Sinha Ajay Kumar, Prof. Shyam Kumar Inturi and Prof. Onkar Chothe for coordinating the Logistics and VIP & Guest Management; Dr. Kedar Phadke and Dr. D'Souza Lyseth for coordinating the activities related to hospitality and food; and Dr. P. Ammani and Dr. Savitha Chilakamarri for coordinating the speaker arrangements, proceedings and cultural events in the auditorium. We also appreciate the efforts of Dr. Pramadha, Prof. K. Ravindranath and Dr. Vinay for coordinating the events at various venues in coordination with the technical team.

We are grateful to Dr. V. Sri Hari, Dr. Lyseth D. Souza, Dr. P. Vimlesh and Dr. P. Ammani for coordinating the Delegate Reception and Registration and Prof. Mamillapalli Raja Sekhar and Dr. Muralidhar P. for coordinating the procurement and arrangement of the conference kit. Prof. Onkar Chothe merits special recognition for designing the conference's posters and other promotional materials.

We take this opportunity to appreciate the efforts of our support teams including the IT team: Mr. P. Sivakumar, Mr. S. Praveen Kumar and Mr. P. Sridhar; the administrative and accounts team: Mr. S. Subrahmanyam, Mr. V. Giri Prasad, Ms. Haritha Davuluri, Mr. Shaik Sammad, Mr. M. Suresh Babu and others; Mr. Amol in the DG's office; and Ms. Savita Alandkar for their support in organizing this conference. We would also acknowledge our support staff, operators, drivers, technical staff, house-keeping and security personnel who toiled day and night to make this event even more successful and are greatly appreciated.

The mentorship of Dr. Vikrant Yadav, the student coordinator who coordinated the student volunteers for various technical and cultural activities, deserves special appreciation. We appreciate the team efforts of the students led by Mr. Adith, Ms. Abhirami, Mr. Digen, Ms. Farha, Mr. Viraj, Mr. Debaditya, Mr. Hirosh, Mr. Venu, Mr. Sumanth, Mr. Md. Zain, Ms. Afreen, Mr. Anuranjan Dung Dun, Ms. Rupali and Ms. Alisha for their support in organizing the event and making it a wonderful success.

We hope that all the participants in ILCC 2022 had a joyful and fruitful learning experience in this one-of-its-kind industry–academia conclave.

Hyderabad, India

Dr. Venkatesan Renganaidu
Dr. Arun Chandramohan
Editors and Conveners—ILCC 2022

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About the Editors

Dr. Anil Kashyap is the first President and Chancellor of NICMAR University Pune and Hyderabad. He has 30 years of experience in practice, academia and research—both in India and abroad. In his leadership roles, Dr. Kashyap has been Head of UWE Bristol School of Geography and Environmental Management, Deputy Head of Coventry University School of Energy, Environment and Construction, and Founding Professor and Director of RICS School of Real Estate before joining NICMAR as the Director General in September 2021.

His expertise includes Infrastructure Development and Finance, Urban Regeneration, and Real Estate Research. Dr. Kashyap holds a bachelor's degree in Civil Engineering with distinction from NIT Kurukshetra, master's in Urban Planning from the School of Planning & Architecture, New Delhi, and a Ph.D. from the University of Ulster, UK. Dr. Kashyap is Alumnus of Harvard University with training in Higher Education Leadership and Change Management. He is Fellow of the Higher Education Academy of the UK.

Prof. N. Raghavan is currently Professor of Practice, BTCM division, Department of Civil Engineering, Indian Institute of Technology Madras, Director at Institute for Lean Construction Excellence (ILCE), Independent Director at Vadodara-Bharuch Toll Roads Ltd., Panipat Elevated Corridor Ltd., L&T Transportation Infrastructure Ltd., and Member. He obtained a Bachelor of Technology (Civil Engineering) from the Indian Institute of Technology Madras in 1970 and a Master of Technology (Structural Engineering) from the Indian Institute of Technology Bombay in 1976. Professor Raghavan is Elected Fellow of the prestigious INAE (INAE has only 860 Fellows in the country across all disciplines covering academic, industry, and R&D), Fellow of ICE(UK), IofE(I); prestigious SB Joshi Award for Excellence in Structures & Bridges, Chairman of Research Council of CSIR-Central Building Research Institute, Best Overseas Article Award from ICE (UK), Member of International Steering Committee for Lean Construction in Public Sector (LIPS). As Member of the Top Management of L&T ECC Construction Division at retirement, Prof. Raghavan set up and managed as its Chief Executive L&T—Ramboll Consulting Engineers Ltd.; Engagement with different facets of the profession with passion

(Engineering, Consultancy, Construction, Project Management, Academic). He has a patent for a new method of excavation, the patent for precast segmental foundations (being applied). Professor Raghavan published more than 200 international journals and conference papers and six technical books and book chapters and guided 18 M.Tech. project students of IIT Madras.

Dr. Indrasen Singh has over 35 years of experience in teaching, research, administration, strategic planning, institutional reforms, accreditation, and consultancy work. He has been responsible for traffic and transportation departments at ICT (P) Limited, Green Park New Delhi, NICMAR Delhi, and NICMAR Goa Campus. He was the founder Professor and Dean of NICMAR Goa Campus and developed the M.Tech. Programme in structural engineering, transportation engineering, and environmental engineering in civil engineering at Lovely Professional University, Punjab. Dr. Singh has received 41 awards and has published 173 scientific technical papers in various national, international journals and conferences, and has worked on 45 major highway and transportation projects. He has guided one Ph.D. thesis, two M.S. theses, nine M.Tech. theses, and 187 PG theses.

Dr. Singh has taught 18 subjects and developed 13 at the PG level. He has experience in academics and industry, as well as expertise in World Bank/ADB-funded projects. His many research papers are listed on the Transportation Research Board, USA for reference. He is a Fellow of the Institution of Engineers (India) and a life member of the Indian Roads Congress, Indian Buildings Congress, and Institute of Urban Transport. Dr. Singh has leadership qualities and has led the overall management and administration of NICMAR University, Hyderabad, with a vision to develop the university into a Centre of Excellence.

Dr. Venkatesan Renganaidu is currently Professor and Director of IQAC at the National Institute of Construction Management and Research, Hyderabad. He has been awarded a Ph.D. from the Department of Civil Engineering, IIT Madras, in the area of Construction Management, then pursued his master's in Business Administration with a specialization in Human Resources & System Management from Madurai Kamarajar University, Madurai, and B.E. (Civil) from Maharaja Sayajirao University, Vadodara. Dr. Venkatesan has been associated with the Central Public Works Department (CPWD) in numerous capacities for two decades and took a Voluntary Retirement (VRS), while he was serving as Executive Engineer, later he headed the Management Development Center (MDC) of Consolidated Construction Consortium Ltd. (CCCL), Chennai, and also served as Director in Engineering Project Management Consultancy and Research (EPMCR), an incubated company of IIT Madras. Dr. Venkatesan Renganaidu obtained the "Research Excellence Award" from the National Institute of Construction Management and Research, Pune, Maharashtra, India. He had published ten international peer-reviewed journal papers and two national journal papers and also presented nine international conference papers and three national conference papers. He is also Member board of studies at Vellore Institute of Technology (VIT) Vellore and Chennai.

Dr. Arun Chandramohan, Professor and Dean (Research) and the School of Business Management at NICMAR Hyderabad, is one of the experts in Construction Materials, Construction Scheduling and Risk Assessment, Sustainable construction techniques, and Lean Construction.

Dr. Arun graduated in Civil Engineering from Calicut Regional Engineering College, Kerala (Presently NIT Calicut) in the year 1999. He did his master's in Construction Engineering and Management in 2001 and Ph.D. in the area of Construction Management in the year 2004 from the College of Engineering, Guindy, Chennai.

Construction of 80 m Steel Open Web Girder Over Gaddigodam Railway Span in Nagpur—A Lean Approach



Sarbajit Roy Choudhury, Pradeep Kumar, and Roshan Lal

Abstract The Nagpur Metro Reach-2 viaduct project is a unique project from many aspects. The project team overcame all kind of challenges including the global pandemic COVID-19 and was truly focused to achieve the given target. The project team used various innovative techniques, did detailed planning, adopted time saving approaches by adopting Lean approaches and team work to achieve the stiff target of completion of 3 months for the erection of 80 m open web girder over the railway tracks. The safety and quality parameters were given highest priority during the process of superstructure erection. Unique challenges and working on new methodology and continual guidance from specialists motivated the team to accomplish the job. Apart from presence of railway tracks and OHE lines, launching methodology and time constraint, transportation of oversized and heavy components of truss was one of the problems which was mitigated by prior checking of route by dry run of ODC trailer. The 80 m steel span launching included assembly of members over temporary structures in three parts, pulling of assembled part over railway tracks and assembly of balance members over temporary structures. Part 1 and Part 2 of the structure were assembled over temporary supports in parallel, thereby reducing the waiting time for successor activities. The project team analysed the total workflow and the cycle time in order to remove the waste to achieve the minimum time required for superstructure erection. The findings in this paper demonstrate that through effective application of Lean methods waste can be removed from the workflow and stiff completion targets can be achieved.

Keywords Workflow · Process · Waiting time · Waste · Parallel activity

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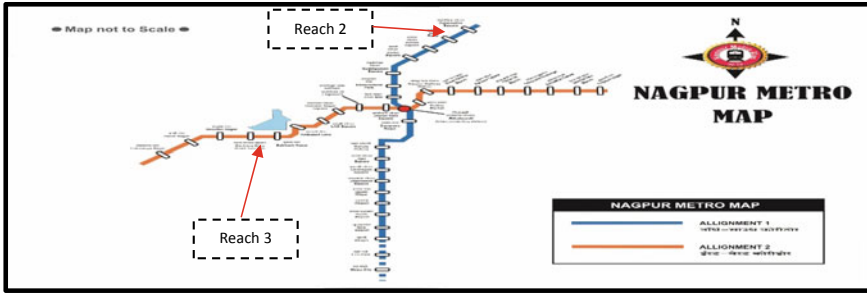


Fig. 1 Route map of Nagpur metro

1 Definition of Waste

In Lean thinking waste involves many kinds of waste, including the waste of excessive human motion, over production, etc., and to make the process more that reduces cost and improves overall revenue. Under the Lean system, seven wastes are identified: overproduction, inventory, motion, defects, over-processing, waiting, and transport.

2 Introduction

Nagpur Metro Phase-1 consists of two corridors North–South and East–West with a total length of 41.7 km out of which 17.087 km, i.e. 41% of the viaduct was awarded to AFCONS in Reach-2 (North–South corridor) and Reach-3 (East–West corridor) stretches. AFCONS has executed more than 51% of the value of civil structure for Nagpur Metro Project. AFCONS has executed Reach-2 package in North–South corridor which consists of India’s longest 5 km double decker structure for metro viaduct and 1.7 km metro viaduct structure which starts from Automotive Square on Kamptee Road and ends at Sitabuldi (Fig. 1). AFCONS had also executed 11 spans and 4 elevated stations in Reach-1 of Nagpur Metro Project.

3 Project Details

Nagpur Metro Phase-1 consists of two corridors North–South and East–West with a total length of 41.7 km out of which 17.087 km, i.e. 41% of the viaduct was awarded to AFCONS in Reach-2 (North–South corridor) and Reach-3 (East–West corridor) stretches. AFCONS has executed more than 51% of the value of civil structure for Nagpur Metro Project. AFCONS has executed Reach-2 package in North–South corridor which consists of India’s longest 5 km double decker structure for metro viaduct and 1.7 km metro viaduct structure which starts from Automotive Square on

Kamptee Road and ends at Sitabuldi (Fig. 1). AFCONS had also executed 11 spans and 4 elevated stations in Reach 1 of Nagpur Metro Project.

In order to commission the metro viaduct structure by mid of April 2022, the client gave a 3 months target on 18 December 2021 after discussion between MD Maha Metro and EVC of AFCONS to complete the 80 m railway span open web girder by 17 March 2022 in order to facilitate the opening of the full Reach-2 metro stretch. As per the approved baseline program, the total construction duration of the 80 m railway span was approx. 7.5 months.

4 Challenges and Methodology

The 80 m railway span (Fig. 2) is located at the most congested area of the alignment where access to the site for equipment movement and material storage is quite next to impossible. The stretch is also part on the major connectivity route between rural and urban location of Nagpur due to which very high traffic volume is present along the stretch. At the crossing, 150 number of railway movement per day, i.e. roughly more than average 6 trips per hour with peak railway movement of 8 trips per hour, is scheduled.

Due to the presence of railway track, any works carried out within the railway boundary would require permission from the railway authorities. The establishments/shops, workshops along the work location led to very limited options for erection of the OWG. Different erection/launching schemes were explored—Full span launching with nose from either side of the railway tracks, incremental launching, etc. However, all these launching methods did not fructify due to non-availability of land and presence of utilities—large diameter water lines at the proposed temporary foundation



Fig. 2 80 m railway span open web girder general arrangement

locations. The difficult part of the substructure construction was to build the 4 temporary supports on the railway embankment. The constraints were evolving one after the other and at a point of time during the planning stage it looked like the construction works will be seriously jeopardized [1].

The project team proposed the part erection and part launching scheme—a hybrid model which have never been tried for any steel structure crossing over the railway tracks of the Indian Railways. The hybrid model of launching the 80 m truss (Figs. 3, 4, 5 and 6) was planned to be done in 3 parts, namely

Part 1—20 m—2 panels stationary at one end (Weight—387.5 MT).

Part 2—30 m—3 panels erected and pulled to connect with Part 1 (Weight—581.25 MT).

Part 3—30 m—3 panels erected behind the Part 2 in continuation after completion of Part 2 launching (Weight—581.25 MT).

In total approx. 80,000 nos. of HSFG bolts (M24 10.9 grade) were used for the assembling of the structure and 28 nos. of torqueing machines including 5 nos. electronic high-speed torque machines brought from other site was used for the torqueing purposes. In order to expedite the design works of the temporary structure, local

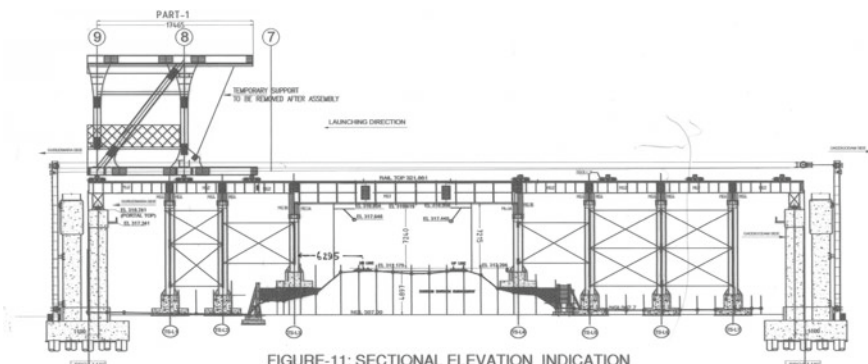
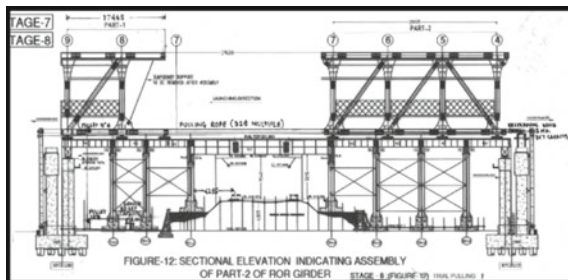


Fig. 3 Erection of PART-1

Fig. 4 Erection of PART-2



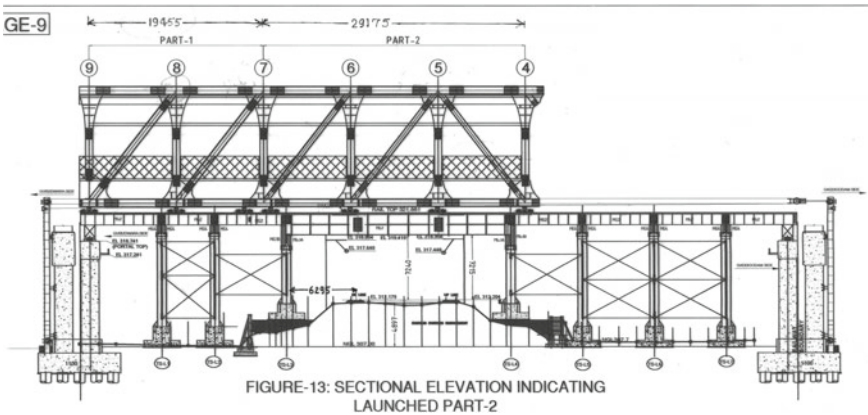
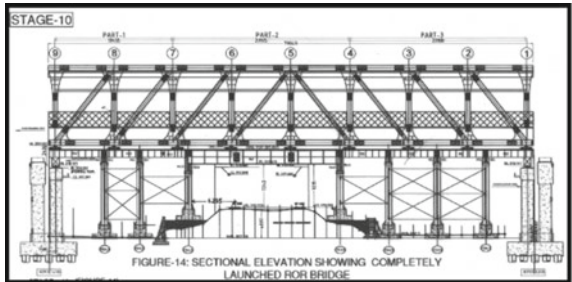


Fig. 5 Pulling of PART-2

Fig. 6 Assembly of balance parts



designer from Nagpur was appointed as per client request. Also, as per client request additional third-party reviewer for the temporary works design was appointed.

The review by client appointed DDC was started in October 2022 and completed in 24 December 2022. Additional fabrication works of 150 tons were carried out to meet the DDC requirements (additional bracings in track girders, round stiffeners in liners, etc.). The project team deployed total 32 nos. of welders (16 nos. in each shift) to complete the additional works of strengthening works of the temporary structure. The project team identified different activities which were to be carried out during the day and night shift to reduce the duration of the works [2] by doing parallel activities and reduce the waiting time (Table 1).

The project team did detail planning to identify and remove nonvalue adding activities and making activities in parallel in order to reduce the time cycle. Figure 7 shows the areas where improvements (Fig. 7) were made to achieve the schedule completion date.

The project team also gave immense importance to avoid any defects during the fabrication and erection of the structural steel members like proper alignment during member erection, thorough checking during the full trial assembly, checking the

Table 1 Day and night time activities for railway span

	Day time activities		Night time activities
a	Structural members erection	a	Structural members erection
b	Members assembly	b	Members assembly
c	Bolting and torqueing	c	Bolting and torqueing
d	Sand blasting and painting at fabrication yard	d	Sand blasting and painting at fabrication yard
		e	Members transport to site from fabrication yard
		f	Crane shifting

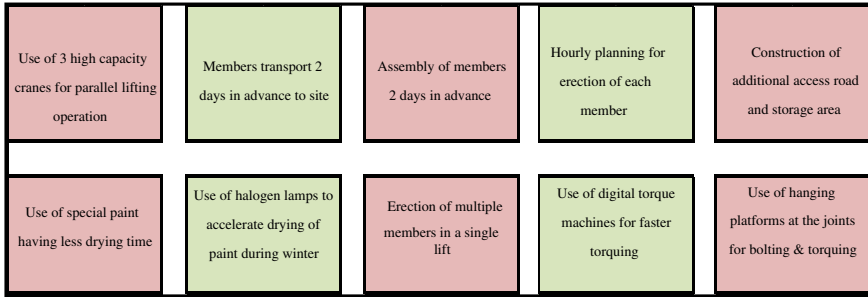


Fig. 7 Areas of improvement

bolting and torqueing of each joint from the very beginning, continuous monitoring of the whole structure during the erection for orientation and levels of the structure.

5 Use of 3 Nos. of High-Capacity Cranes for Parallel Lifting Operation

Constraint: At the initial stage of the planning, the erection of the members at railway span for members erection was planned with two numbers of high-capacity cranes. However, in order to achieve the stiff completion target given by client and to do more numbers of parallel members erection, the project team decided to remove waiting time from the process.

Lean Method: In order to avoid waiting time, the project team decided to use an additional one number of high-capacity crane. This helped to increase the number of parallel lifts per day and meet the target date of erection completion (Fig. 8).



Fig. 8 Use of 3 nos. of cranes for parallel erection of members

6 Members Transport 2 Days in Advance to Site

Constraint: The fabrication of the steel structure was carried out at Nagpur. The fabrication yard was located approx. 35 kms from the erection site. As multiple cranes were deployed for erection purposes, so it was the highest priority for the project team to feed the members to all the cranes in a timely manner and to eliminate the waiting time between the two successive lifts.

Lean Method: The delay in the transportation of the structural members was avoided by transporting the members to site 2 days in advance in order to ensure that cranes do not become idle at any point of time. To ensure smooth transport of trailers, the project team deployed 6 nos. of retired police officers with pilot cars to escort the trailers from the fabrication yard to the site.

The transport of members by trailers were planned in advance, and type of trailers to be used (Normal, ODC) were identified in advance a list of trailers (refer Table 2) for structural member transportation was prepared and used for monitoring purposes.

7 Assembly of Members 2 Days in Advance

Constraint: Waiting for assembled structural steel members for lifting.

Lean Method: The project team ensured that the assembly of the members on ground is completed well in advance, so that there is no waiting time for the cranes during the lifting operation. The project team ensured that the bolting and torquing is completed on time and checking by client is also completed well in advance. By

Table 2 Member-wise erection program with trailer details

Sl. No.	Member description	Bolt	Mark number	Unit weight (Kg's)	Erection part number	Quantity (Nos.)	Weight (Kg's)	Grid #
PART # 1—Part 2								
1	FLY OVER STRINGER BEAM—FSB1/3	48	9—7 FSB 1/3	1928.75	1	1	1928.75	9 to 7
2	FLY OVER STRINGER BEAM—FSB1/4	48	9—7 FSB 1/4	1928.76	1	1	1928.76	9 to 7
3	FLY OVER STRINGER BEAM—FSB1/5	48	9—7 FSB 1/5	1928.66	1	1	1928.66	9 to 7
4	FLY OVER STRINGER BEAM—FSB1/32	48	9—7 FSB 1/32	1928.66	1	1	1928.66	9 to 7
5	FLY OVER STRINGER BEAM—FSB1/32	48	9—7 FSB 1/32	1928.66	1	1	1928.66	9 to 7
6	FLY OVER STRINGER BEAM—FSB1/32	48	9—7 FSB 1/32	1928.66	1	1	1928.66	9 to 7
7	FLY OVER CROSS DIAPHRAGM FCD/1	74	9—7 FCD 1	401.94	1	1	401.94	9 to 7
8	FLY OVER CROSS DIAPHRAGM FCD/2	74	9—7 FCD 2	401.94	1	1	401.94	9 to 7
9	FLY OVER CROSS DIAPHRAGM FCD/3	74	9—7 FCD 3	399.97	1	1	399.97	9 to 7
10	FLY OVER CROSS DIAPHRAGM FCD/4	74	9—7 FCD 4	401.94	1	1	401.94	9 to 7
11	FLY OVER CROSS DIAPHRAGM FCD/5	74	9—7 FCD 5	401.94	1	1	401.94	9 to 7
12	BOTTOM BRACING BB1/1	40	9—7 BB 1/1	572.49	1	1	572.49	9 to 7

(continued)

Table 2 (continued)

Sl. No	Member description	04.01.2022											
		Day shift						Night shift					
		No of bolts Required for permanent joint	For crane release	Duration (Hrs.)	Weight	Trailer type	No. of trailers	No of bolts Required for permanent joint	For crane release	Duration (Hrs.)	Weight	Trailer type	No. of trailers
PART # 1—Part 2													
1	FLY OVER STRINGER BEAM—FSBI/3	48	24	2	1928.75	Normal	1						
2	FLY OVER STRINGER BEAM—FSBI/4	48	24	2	1928.76	Normal	1						
3	FLY OVER STRINGER BEAM—FSBI/5	48	24	2	1928.66	Normal	1						
4	FLY OVER STRINGER BEAM—FSBI/32	48	24	2	1928.66	Normal	1						
5	FLY OVER STRINGER BEAM—FSBI/32	48	24	2	1928.66	Normal	1						
6	FLY OVER STRINGER BEAM—FSBI/32	48	24	1	1928.66	Normal	1						

(continued)

Table 2 (continued)

Sl. No	Member description	04.01.2022														
		Day shift						Night shift								
		No of bolts Required for permanent joint		For crane release		Duration (Hrs.)	Weight	Trailer type	No. of trailers	No of bolts Required for permanent joint		For crane release		Duration (Hrs.)	Weight	Trailer type
7	FLY OVER CROSS DIAPHRAGM FCD/1									74		37	2	401.94	Normal	1
8	FLY OVER CROSS DIAPHRAGM FCD/2									74		37	2	401.94	Normal	
9	FLY OVER CROSS DIAPHRAGM FCD/3									74		37	2	399.97	Normal	
10	FLY OVER CROSS DIAPHRAGM FCD/4									74		37	2	401.94	Normal	
11	FLY OVER CROSS DIAPHRAGM FCD/5									74		37	2	401.94	Normal	1
12	BOTTOM BRACING/BB/1									40		20	1	572.49	Normal	

adopting this method, the project team ensured that there are no defects in assembly of members and torquing of bolts. This approach helped the site team to achieve faster work progress with minimum time wastage.

8 Hourly Planning for the Erection of Each Member

Constraint: Delay in structural steel members erection.

Lean Method: The project team did the detail planning for each member erection for Part 1, Part 2 and Part 3 members. The detailing was done by the team for each shift (day and night) in order to control the erection time of each crane and monitor any deviation from the planned duration. The shift-wise lifting program including the number of bolts required in each joint (refer Table 2) for crane releasing before erection of next member helped the project team to reduce the time cycle of each lift. All the required bolts and nuts for each individual joint were kept ready in advance to avoid any wastage of time and avoiding use of wrong bolts and replacement of the same at a later stage.

9 Construction of Additional Access Road and Storage Area

Constraint: To avoid delay in transportation and shortage of storage area.

Lean Method: The project team developed additional access road and storage area near to the erection site to store and assemble structural members two days in advance. The temporary area and road development along the railway tracks were completed within 3 days (total volume approx. 11,000 m³) after taking permission from the railway authorities. The creation of additional access road and storage area (Fig. 9) helped the project team to avoid any delays and idling of cranes.

The additional storage area also helped for materials stacking for deck slab construction in advance as deck slab construction was completed immediately after truss lowering operation was completed.

10 Use of Special Paint Having Less Drying Time

Constraint: To reduce waiting time during the painting of the members.