Scheduling of FRP composite bridges using 'Primavera' Software

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Abstract— Scheduling a construction project means to coordinate resources of workers, machines and materials in a time-efficient way in order to realize a construction project within the projected time and costs.

The use of fibre reinforced polymer (FRP) composites, space age technology for bridge construction is increasing and time saving. New breeds of this high performance and innovative material developed in the last 70 years are making headway into the civil and bridge infrastructures. Structural components for hybrid bridge construction such as FRP deck panels and slabs, reinforcing elements, cable and tendon systems, and laminates have been successfully demonstrated in highway bridges.

Index Terms— Fibre Reinforced Polymer , FRP Composites, Scheduling, Primavera, Baseline, P6, Bridge Engineering.

1 INTRODUCTION

The construction industry today is revolutionizing in two major ways. One way is the advancement in high-performance construction materials, such as composites made from fibre reinforced polymer (FRP) and other is the development of realistic construction schedules and strict adherence to them. Use of composite in constructions practices is a growing trend and is gaining acceptance from civil engineers. Bridge engineering is benefitting from the introduction of composites. It has various advantages over traditional materials and they are its high tensile strength to weight ratio, ability to be modelled into various shapes, resistance to environmental changes.

The most highly developed application to date is the use of advanced composites in repair of bridge columns and other supporting elements to improve their ductility for seismic resistance.

In the field of civil engineering, most of the use of FRP is confined to repairing and strengthening of structures. FRP is being used for new construction also in many countries; none could be traced in India. The material is still considered relatively new in this part of the world.

But FPR Bridges are being constructed from over 3 decades in countries like China and USA.

These bridges are a greener alternative to concrete and steel construction and saves money, reduces fabrication timelines, lessens transportation costs, accelerates bridge construction, and dramatically reduces lifetime maintenance costs.

Scheduling of a construction project is more important today than ever before. Most Bridge construction projects now involve traffic disruption. It is important that Designers and Contractors understand that work must be planned and executed efficiently to minimize these disruptions.

The method based on a simulation of construction works, taking into account the available resources and the interdependencies between individual tasks is necessary.

Projects are often affected by unscheduled constraints and limitations that give reason to deviate from the formerly optimized plan, and to find ad-hoc solutions.

This document will first present the basic scheduling of FRP composite bridge using P6 software, including all the steps and phases present in the construction process and uses of FRP relevant to civil engineering applications. Then the application of FRP composite in bridge engineering will be investigated, through a case study.

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2 SCHEDULING

In developing a schedule, three basic items make CPM scheduling work:

- Clearly defined activities.
- Realistic duration's.
- Good logic.

Standard factors that shall be taken into account when preparing a Construction Schedule include:

1. Scheduling the advertisement of small, short duration projects in order to allow construction to be completed in one construction season (Designer Contract Time Determination only).
2. Seasonal limitations such as concrete construction, paving, Hot Mix Asphalt (HMA) availability, curb, placement of long life traffic stripes, landscaping and bridge painting.
3. Utility relocation's (each utility treated separately - work on the same pole line must be treated sequentially, not concurrently).
4. Various services interruptions during rainy season. Normally from June 1to October 1, to be verified through the Metrological Department.

5. No water service interruptions should occur during the summer months. Normally from March 1 to June 30 to be verified through the Concerned Unit.
6. Right-of-way availability (each parcel treated separately).
7. Work hour restrictions due to staging and traffic volumes.
8. Marine, bridge openings, or railroad traffic.
9. Staged construction.
10. Concrete curing time.
11. Embankment settlement time.
12. Coordination with other projects.
13. Rainy season shutdown.
14. Working drawing processing and approvals (each one treated separately).
15. Availability, fabrication and delivery of materials.
16. Permit restrictions.
17. Work area restrictions (wetlands, historic sites, parkland, etc.).
18. Hazardous material excavation and disposal.
19. Payment restrictions due to limits in multi-year funding.
20. Work restrictions due to local activities, holiday seasons on roads with shopping centers, or in seasonal areas such as shore communities.
21. Impacts to Authorities. (NHAI)

2.1 Scheduling Software

The project involves use of Primavera P6 software as the scheduling software to maintain a database of all Capital Program Management projects.
This database will contain both
a) Capital Program Management's schedule and budget for the entire design process for each project and
b) The Designer's and Contractor's schedules for the proposed construction work required to complete the project.
The Designer will begin development of a construction schedule starting with a preliminary schedule at Initial Design and reaching the final schedule at the Final Design Submission. The Contractor will begin development of a construction schedule at the Award of
Contract starting with the preliminary schedule and continue throughout the construction contract with the submission of a baseline schedule and monthly updates. This manual covers the construction scheduling portion from the initial design until the completion of construction.

2.2 Regular Practices in P6

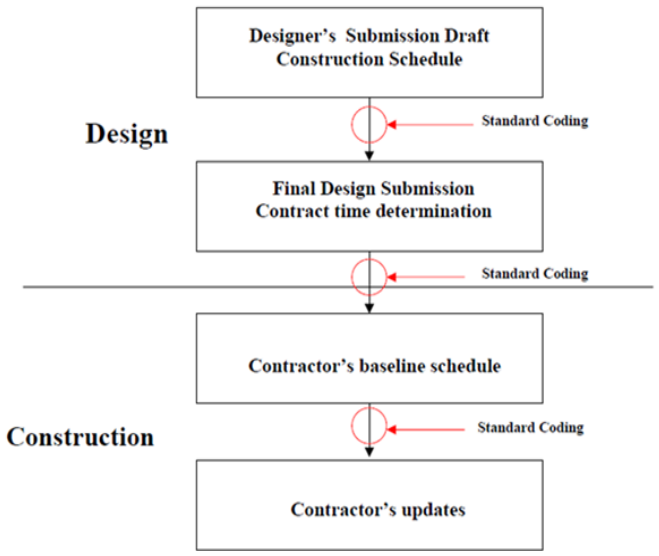
1. Negative lags will not be permitted.
2. Do not use a Finish to Start relationship with a lag. An activity must be added to represent the lag time.
3. A project shall have one beginning and one end. All activities shall have a predecessor and successor except the project's start and finish milestones. No "Open Ends" will be permitted.
4. Durations of work activities shall not exceed the update cycle. The Department requires the update cycle to be prepared monthly.
5. "Suspension of Dates" will not be permitted. An activity must be added.
6. If an activity has a Start-to-Start relationship - it shall be closed with a Finish-to- Finish or Finish-to-Start relationship. (No open ends)
7. The completion date of the CPM schedule shall be the completion date in Subsection 108.10 of the project's Special Provisions, which shall be input as a Finish Milestone with a Late Finish Constraint. All intermediate milestones (Interim Completion Dates) required in the Contract shall be shown in proper logical sequence and input as either the "Start-no-Earlier-Than" or "Finish-no-Later-Than" date. Mandatory Finish and Mandatory Starts shall not be used.
8. When updating, all "Out of Sequence" activities shall be corrected to reflect the current construction operations.
9. Original durations shall not be changed from the approved Baseline Schedule.

2.3 Standard Coding

As a means of monitoring progress schedules, every Department with the help of Consultant and Construction industries develops a common coding structure and procedures to be utilized from design through construction. A Designer or Contractor shall utilize the Primavera template project containing the latest standard coding provided from the Department's web site or will be sent upon request.

2.4 Development of Project Schedule

As you track progress through your project, you can review the differences between planned, scheduled, and actual work. This helps you assess whether work on your project is progressing as expected. You can compare work amounts for tasks as a whole, or for resources and their individual assignments.



If you saved a baseline, then your original planned work amounts are stored in the **Baseline** field. With this field, you can compare work amounts in your original plan to currently scheduled work amounts.

The **Variance** field shows the calculated variance between planned and scheduled work, that is, the difference between the **Baseline** and **Work** fields.

The **Tracking Gantt** view displays two task bars, one on top of the other, for each task. The lower bar shows baseline start and finish dates, and the upper bar shows scheduled start and finish dates so that you can see the difference between your plan and the current schedule.

If you know where slack exists in your schedule, you can move tasks when certain phases of the schedule have no slack and other phases have too much. Slack values may also indicate a schedule inconsistency. For example, a negative slack value occurs when one task has a finish-to-start dependency with a successor task, but the successor task has a Must Start On constraint that is earlier than the end of the first task. Negative slack can also occur when a task is scheduled to finish after its deadline date.

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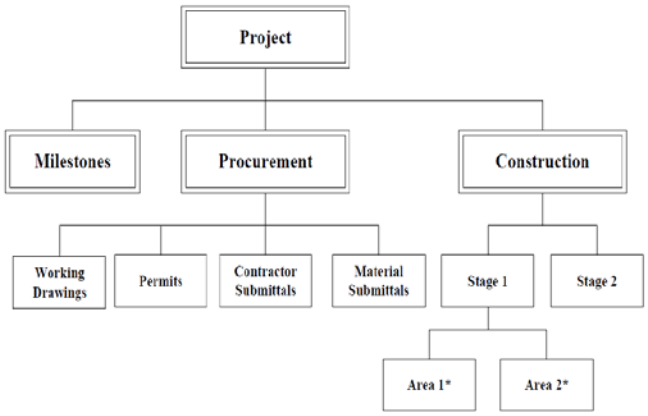
2.5 WBS (Design / Construction Template)



1 MILESTONES

ACTIVITY ID	ACTIVITY DESCRIPTION
M100	Advertise Date (Start Milestone)
M200	Bid Date (Start Milestone)
M300	Award Date (Start Milestone)
M400	Start Design Work (Design/Build only) (Start Milestone)
M480	Complete Design Work (Design/Build only) (Finish Milestone)
M500	Construction Start Date (Start Milestone)
M600	Stage_ Complete (Finish Milestone)
M700	Interim Completion Date(s) (Finish Milestone)
M800	Inspection Date(s) (Finish Milestone)
M900	Substantial Completion (Finish Milestone)
M950	Completion (Finish Milestone)

2 PROCUREMENT

P.CS Contractor Submittals (Not Materials)

P.CS.01 Safety Plan
P.CS.02 Night Lighting
P.CS.03 Demolition
P.CS.04 Disposal
P.CS.05 Paving
P.CS.06 Steel Erection
P.CS.07 Health and Safety Plan
P.CS.08 Deck Placement

P.PP Permits
- P.PP.01 Environmental
- P.PP.02 Dewatering

P.MS Material Submittals (Long Lead Items)
- P.MS .01 Concrete
- P.MS .02 Structural Steel
- P.MS .03 Asphalt
- P.MS .04 Electrical
- P.MS .05 Sheeting/Cofferdam

P.WD Working Drawings
- P.WD .01 Bridge Working Drawings
  - P.WD.01.01 Bridge Working Drawings Requiring Design
    - P.WD.01.01.01 Structural Steel Working Drawings
    - P.WD.01.01.02 Structural Bearings
    - P.WD.01.01.03 Pre-stressed Concrete Beams
    - P.WD.01.01.04 Pre-stressed Concrete Piles
    - P.WD.01.01.05 Expansion Dams
    - P.WD.01.01.06 Coffer-dams
    - P.WD.01.01.07 Sheeting
    - P.WD.01.01.08 Machinery for Movable Bridges
    - P.WD.01.01.09 Electrical Items for Movable Bridges
    - P.WD.01.01.10 Precast Concrete Culverts
    - P.WD.01.01.11 Steel Bridge Deck Forms
    - P.WD.01.01.12 Prefabri-cated Modular Walls
    - P.WD.01.01.13 Mechani-cal Stabilized Earth (MSE) Walls
    - P.WD.01.01.14 Concrete Crib Walls
    - P.WD.01.01.15 Alternate Retaining Wall Design
    - P.WD.01.01.16 Tempo-rary Structures
    - P.WD.01.01.17 Tempo-rary Shielding
    - P.WD.01.01.18 Electrical Items not pre-approved
  - P.WD.01.02 Bridge Working Drawings Not Requiring Design
    - P.WD.01.02.01 Structural Steel Working Drawings
    - P.WD.01.02.02 Structural Bearings
    - P.WD.01.02.03 Prestressed Concrete Beams
    - P.WD.01.02.04 Prestressed Concrete Piles
    - P.WD.01.02.05 Expansion Dams
    - P.WD.01.02.06 Cofferdams
    - P.WD.01.02.07 Machinery for Movable Bridges
    - P.WD.01.02.08 Electrical Items for Movable Bridges
    - P.WD.01.02.09 Strip Seals
    - P.WD.01.02.10 Armored Deck Joints
    - P.WD.01.02.11 Bridge Storm Drains
    - P.WD.01.02.12 Sign Support Structures
    - P.WD.01.02.13 GA Sign Support Posts
    - P.WD.01.02.14 Noise Barriers
    - P.WD.01.02.15 Bridge Railings and Fencing An-chorages
    - P.WD.01.02.16 Sign Legends
- P.WD .02 Road Working Drawings
  - P.WD.02.01 Road requiring de-sign
    - P.WD.02.01.01 Impact at-tenuators
    - P.WD.02.01.02 Sheeting
    - P.WD.02.01.03 Electrical items not pre-approved
  - P.WD.02.02 Road not requiring design
    - P.WD.02.02.01 Impact at-tenuators
    - P.WD.02.02.02 Sign leg-ends
    - P.WD.02.02.03 Recy-cled/synthetic rout-ed spacers

.3 CONSTRUCTION

STAGES INVOLVED IN BRIDGE CONTRUCTION

STAGE A
- DIVE Underwater Inspection
- SHEE Sheeting
- BDST Clearing site, bridge

STAGE B
- BEXC Bridge Excavation

COCU Construction of Concrete culverts
PILE Construction of Piles
WALL Noise Barrier arrangements
BRST Temporary Shielding

STAGE C
COFF Cofferdams Construction
REIN Reinforcing Steel and FRP Bars

STAGE D
DECK Deck Construction
CONS Pouring Structural Concrete
STEL Using FRP bars.
PREC Precast/Prestressed Beams
CONS1 Pouring Structural Concrete
STEL1 Using FRP bars.

STAGE E
OSIG Overhead/Cantilever signs
BMIC Bridge Miscellaneous Construction(Fence, railing, joints, guiderail etc.)

C.00 Bridge Construction
C.01 Stage 1
C.01.1A Stage A
C.01.1B Stage B
C.01.1C Stage C
C.01.1D Stage D
C.01.1E Stage E
C.02 Stage 2
C.02.2A Stage A
C.02.2B Stage B
C.02.2C Stage C
C.02.2D Stage D
C.02.2E Stage E
C.03 Stage 3
C.03.3A Stage A
C.03.3B Stage B
C.03.3C Stage C
C.03.3D Stage D
C.03.3E Stage E
C.04 Stage 4
C.04.4A Stage A
C.04.4B Stage B
C.04.4C Stage C
C.04.4D Stage D
C.04.4E Stage E
C.05 Stage 5
C.05.5A Stage A
C.05.5B Stage B
C.05.5C Stage C
C.05.5D Stage D
C.05.5E Stage E
C.06 Stage 6
C.06.6A Stage A
C.06.6B Stage B
C.06.6C Stage C
C.06.6D Stage D
C.06.6E Stage E
C. 07 Stage 7
C.07.7A Stage A
C.07.7B Stage B
C.07.7C Stage C
C.07.7D Stage D
C.07.7E Stage E
C.10 Road Construction
C.10.Stage 1
C.10.1A Arrangement of Temporary Lighting
C.10.1B Demolition work if any
C.10.1C Clearing site items
C.10.1D Construction of Drainage Pattern
C.10.1E Excavation of Earthwork items
C.10.Stage 2
C.10.2A Procurement of Asphalt Pavement items
C.10.2B Procurement & Installation of of Landscape items
C.10.2C Procurement of Utility items
C.10.2D Procurement of Miscellaneous items
C.10.2E Procurement & Installation of of Electrical and Signal items
C.10.Stage 3
C.10.3A Procurement of Aggregates
C.10.3B Construction of Concrete Pavement
C.10.3C Construction of Approach and Transition Slabs
C.10.3D Construction of Sidewalks and Driveways
C.10.Stage 4
C.10.4A Construction of Fence
C.10.4B Construction of Beam Guide Rail
C.10.Stage 5
C.10.5A Removal of Concrete Base
C.10.5B Procurement & Installation of of Curb items
C.10.5C Procurement & Installation of Traffic stripes, signs and delineators
C.10.5D Removal of curb
C.10.5E Maintenance of traffic
C.20 Final Cleanout.

2.6 Advantages of FRP

Use of FRP for confinement has proved to be effective retrofitting and strengthening application. The confinement in seismically active regions has proved to be one of the early applications of FRP materials in infrastructure applications.

Easy in transportation, can be installed easily.

- Light weight. Hence, very high strength to weight ratio.
- High fatigue resistance.
- Joints can be easily avoided as they are available in desired length.

3 CONCLUSION

FRP is an increasing trend in bridge Engineering. It is a new chapter with future promises in civil construction. The application of FRP in civil engineering is showing upward trend in India and China, however, FRP is still a specialty item. To improve this situation, civil engineering and their extension programs must provide sufficient training on unique features of FRPs so that engineers could design or specify them in construction

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