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Jaipur Metro Rail Project:
Construction of metro in heritage city of Jaipur and opportunities for usage of Geospatial technology

by
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Executive Director (Civil), JMRC

Hyderabad, January 2018
Jaipur (the Pink City) is strategically located, is a heritage city and a major tourist destination.

- With a population of 3.1 million in 2011 and an annual population growth of 4.6%, it is one of the fastest growing 3 million plus cities in India (*Population 8.1 m by 2031*).
- Jaipur has about 2 million private vehicles and the lowest share (19%) of public transport among 3 million plus cities of the country.
- CMP (2010) prepared by M/s Wilbur Smith (now CDM Smith) recommended Metro on 2 major corridors having a PHPDT >10,000.
Project at a Glance

Phase-I
(E-W Corridor)
PHPDT 11264

Phase-II
(N-S Corridor)
PHPDT 12901
<table>
<thead>
<tr>
<th>Phase</th>
<th>Length (in kms)</th>
<th>No. of Stations</th>
<th>Projected Completion Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Elevated</td>
<td>UG</td>
</tr>
<tr>
<td><strong>Phase-I</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mansarover to Badi Chaupar</td>
<td>12.0</td>
<td>9.1</td>
<td>2.9</td>
</tr>
<tr>
<td><strong>Phase-IA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mansarover to Chandpole</td>
<td>9.6</td>
<td>9.1</td>
<td>0.5</td>
</tr>
<tr>
<td><em>Already Commissioned</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Phase-IB</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chandpole to Badi Chaupar</td>
<td>2.4</td>
<td>-</td>
<td>2.4</td>
</tr>
<tr>
<td><em>Under Construction</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Phase-II</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitapura to Ambabari</td>
<td>23.8</td>
<td>13.8</td>
<td>10</td>
</tr>
</tbody>
</table>

*Underground corridor has been planned in and around the walled city and aiport*
Phase IA
(Mansarovar to Chandpole: 9.6 kms/ 9 stns)

- Work commenced on 24.02.2011
- Line opened for public on 03.06.2015
- Getting completed in about 4 yrs and a quarter, it is one of the fastest implemented metro projects.
- Jaipur Metro has been attracting decent ridership since the day of commercial opening and crossed ridership of 1 lac on 07.06.2015.
- Jaipur Metro has received a good response and daily average ridership of 21464 has been achieved in the first thirty one months.
Phase IB
(Chandpole to Badi Chaupar: 2.4 kms/2 stations)

- This phase is entirely underground and located in the heritage city
- It is being directly executed by JMRC, with DMRC acting as General Consultant
- Prime Minister of India laid the foundation stone of Phase 1B on 21.09.2013.
- M/s. CEC of Taiwan awarded tunnel & station works, through ICB
- Omikron (Greece) is the Structural Design Consultant
- AYESA (Spain) is the Detailed Design Consultant for the project
- TBMs by Robbins (USA)
Construction Plan of the Project

- Boring of 2.0 km-long twin tunnels of 5.6 meter internal diameter using Shield Earth Pressure Balancing technique
- 2 underground stations constructed by cut and cover, top down method at Chhoti Chaupar and Badi Chaupar
- 0.3 km Reversal line in Ramganj Bazar will also be constructed by cut & cover method
- Dismantling of the two Chaupars and restoration to their original shape after construction of Metro stations.
Walled City: Jaipur

Metro Route alignment and stations
Walled City: Jaipur
Planning & Preparation

1. Traffic Management during construction
- Traffic diversion plan were prepared and got approved from traffic Police after stakeholder discussions.
- Barricades with reflectors were provided as per requirement
- Marshals were employed wherever required to ease traffic movement

2. Preservation of heritage look and skyline
- Entire section and both the stations are underground
- Only entry/exit structure will be above ground and facia will be matched with the heritage architecture
- Detailed photography and videography of the two Chaupars, jointly with local bodies, for exact restoration after construction of underground stations

3. Structural safety of the existing buildings & monuments
- Well proven technology being used
  - Earth Pressure Shield TBM for tunnels
  - Top down construction technique for station and Cut & Cover Tunnel

4. Approvals
- NOC from State Archaeology & Museum Department obtained
- Joint Monitoring Committee set up for close monitoring
**Studies Undertaken**

**Environmental Impact Assessment study** (EIA), with technical assistance from ADB

- Safety, Health and Environment conditions of contract includes a Environment Management Plan (EMP) and Environment Monitoring Plan (EMoP)

**Anticipated Environmental Impacts and its Mitigation Measures**

- Numerous Physical Cultural Resources near tunnel surface center-line: Chandpole Gate, Isar Lat or Sargasuli, Jantar Mantar and Hawa Mahal.

<table>
<thead>
<tr>
<th>SN</th>
<th>Monument</th>
<th>Distance from nearest tunnel wall (in meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chandpole Gate</td>
<td>0 Metres</td>
</tr>
<tr>
<td>2</td>
<td>IsarLat (Sargasuli)</td>
<td>10 Metres</td>
</tr>
<tr>
<td>3</td>
<td>Jantar Mantar</td>
<td>78 Metres</td>
</tr>
<tr>
<td>4</td>
<td>Hawa Mahal</td>
<td>46 Metres</td>
</tr>
</tbody>
</table>

- Significant impacts:
  - Vibration & ground settlement
  - Surface noise from excavation
  - Chances of finding artefacts
  - Dust emissions
  - Demolition & restoration of the Chaupars
  - spoil disposal
  - groundwater extraction
  - disruption of essential services
Studies Undertaken...contd

- Impact of natural attenuation of sandy soil, vibration and noise reduction design considered for the rail and train will not result to elevated vibration levels that will cause cosmetic or structural damages to the PCRs.

- The predicted ground settlement under the Chandpole gate.

To ensure the Contractor maintains vibration and noise levels, monitoring coupled with trigger and allowable values were incorporated in the bidding documents.

Soil Investigation

- Detailed soil investigation (29 bores) and a building condition survey were conducted before taking up the work

- The soil is poor in humus with very poor water-retaining capacity.

Ground Water

- The ground water quality is poor at deeper levels.

- The construction site area is notified as an overexploited area and is regulated by Central Ground Water Board.
Building Condition Survey
- Building structures on 30 meters wither side of the metro alignment were surveyed
- Around 3000 building structures were assessed
- Based on the crack, structures were categorised into 6 categories namely, Severe, Very Severe, moderate etc.

Seismicity
- Jaipur City is classified under earthquake low damage risk zone II as per BIS.

GPR Assessment
- Ground penetration radar used to detect buried artifacts, if any
TBM : Tunneling work
Challenges: TBM Under-passing Chandpole Gate
Challenges: TBM Under-passing Chandpole Gate
Legend:

- **Alignment below the chandpole gate**
Chandpole gate Plan with Elevation before Investigation

Ground Level = 439.941
Rail Level = 427.814
Overburden = 6.70 m (approx)
The gap between the crown of tunnel and bottom of foundation was approx 4.5m only. Therefore, it was CRITICAL.

- Main foundation; stone masonry with depth approx. 2.0m ~ 2.4m.
- Below main gate boulder layer was found with depth ~1.5m near the edges and ~1.0m in the mid part.
- Water pipes found below passageways and main arch.

- Water pipeline of 600mm dia and 350mm dia were found in investigation. The flow of water was blocked over the tunnel portion by installing valves at both ends.
Pressure from Media & Public
Automatic Deformation Monitoring System (ADMS)

- Glass prisms were installed on the surface of Chandpole Gate and other critical structures.
- Measurements were taken from the total station to these prisms to convey possible detected movement in the lateral plane (X,Y) and Vertical Plane (Z). (Trigger level 3 mm, Alarm level 4 mm)
- Additional reference prisms were also installed on adjacent structures for effective monitoring of Chandpole Gate.
- This system is fully automated and in operation 24 hrs / 7 days a week. System is equipped with SMS alert functions to warn of threshold limit breaches.

Tilt Meter

- Tilt meters were installed at the corners of the Chandpole Gate and other critical structures to measure any tilt in the structure.
- Tilt sensor is epoxy pasted on the surface of structure and after setting of epoxy the tilt sensor is screwed in bracket. A cable is extended to data logger location and terminated in it for automatic monitoring.
Instrumentation Scheme for Monitoring

Crack Meter
- Crack meters were installed on the surface of Chandpole Gate and other critical structures for measuring the width of Crack in two directions i.e. inside and in UP & DN

Pavement Settlement Marker
- The pavement settlement markers were installed at site to monitor the vertical settlement of road.
- Trigger level 14 mm; Alarm level 18 mm
- Monitoring frequency is once daily during excavation then once weekly
Multi Point Borehole Extensometer (MPBX)

- Various Multi Point Borehole Extensometer (MPBX) were installed to accurately measure distance between sensors with respect to reference plate and thus monitor with passage of time their relative displacement in respect to each other.

Real Time Monitoring System
Instrumentation Scheme for Monitoring

Pavement Settlement Markers and Multi Point Borehole Extensometers

Crack Meter
Building Settlement Marker
Tilt Meter
Pavement Settlement Marker
TBM Online Monitoring
Vibration & Ground Settlement predictions for monuments

Vibration
The Peak Particle Velocity (PPV), a measure of vibrations, during Tunnel Boring attained for each monument along the alignment is as under:

<table>
<thead>
<tr>
<th>Archaeological Monument</th>
<th>TBM Source Rating PPV (mm/s) @ 1m</th>
<th>PPV from TBM in mm/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chandpole Gate</td>
<td>10</td>
<td>0.682</td>
</tr>
<tr>
<td>Isar Lat</td>
<td></td>
<td>0.121</td>
</tr>
<tr>
<td>Jantar Mantar</td>
<td></td>
<td>0.00126</td>
</tr>
<tr>
<td>Hawa Mahal</td>
<td></td>
<td>0.00141</td>
</tr>
</tbody>
</table>

All these were much below the guideline value of 2.0 mm/s for historical buildings and ruins.

Ground Settlement
Maximum settlement from tunnel boring during construction never exceeded trigger value of 4mm and Alarm value of 5 mm.
Challenges during Underground Station construction

**Map Diagram:**

- **Choti Chaupad**
- **Badi Chaupad**
- **Ramganj Chaupad**
Challenges during Underground Station construction

- During the excavation at Chaupars for construction of underground Metro station, old historic water tank were discovered.

Photograph of Chaupar taken during early 1900s, showing old water tank

Photograph of Chaupar taken in 2011, before start metro construction work, showing water fountain

Photograph of Chaupar taken during in 2014, showing excavated old water tank
Old Water Tank found at Chaupars
Proposed Urban Plaza at Chaupar over metro station
Opportunities for Geospatial Technology in Phase 2 of Jaipur Metro (Sitapura to Ambabari)

Geospatial Technology have become key tools for supporting transit business, but have even greater use of these technologies will be required if transit facilities have to meet the challenges of future.
### Status of Phase 2
(Sitapura to Ambabari: 23.8 kms)

- DPR (July 2014) envisages that Phase 2 will become operational in 2020.

<table>
<thead>
<tr>
<th>Total (km)</th>
<th>Elevated Length (km)</th>
<th>UG Length (km)</th>
<th>Total</th>
<th>Elevated Stations</th>
<th>UG Stations</th>
<th>Projected Completion Cost (Rs in Cr.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.8</td>
<td>13.8</td>
<td>10</td>
<td>20</td>
<td>13</td>
<td>7</td>
<td>10,394</td>
</tr>
</tbody>
</table>

- International consultant M/s EGIS Rail (Lead), M/s Egis India (JV) & M/s Feedback Infra JV engaged to review DPR 2014 prepared by DMRC.
Route mapping on satellite Imagery
Main Catchment Area of Phase 2 route

- **Sitapura**: Industrial area and educational hub
- **Airport**: Hotels
- **Tonk Phatak**: Education institutes, High density commercial and residential area
- **SMS Hospital**: Medical Institute & Main Hospital of Rajasthan
- **SMS Stadium**: Recreational center, Educational institutes (coaching centers)
- **Ajmeri Gate**: Entry to Heritage city area (Central Business District), Tourist Spots
- **MI Road**: High street of Jaipur (Main market of Jaipur)
- **Sindhi Camp**: Inter State Bus Terminus, Railway Station, Interchange for Phase 1
- **Collectorate Circle**: Collectorate, District Courts and other govt. offices
- **Ambabari**: Vishwakarma Industrial Area, interchange for BRTS
Geospatial Technology opportunity

Pre Construction
- Optimized route identification
- Identification of land for acquisition
- Construction management
- Traffic and Transport study
- Multimodal transportation planning (e.g., travel demand forecasting),
- Heritage Conservation (Monitoring of heritage structures)
- Demography Analysis,
- Environmental impacts.

Post Construction (O&M)
- Scenario development/visioning,
- Web-based user information systems,
- Asset management systems including infrastructure maintenance management and safety management (including accident analysis),
- Intelligent transportation systems (ITS) applications
- Corridor preservation/right of way,
THANK YOU!