



Delhi Airport Metro Express Line

Have the defects in DMRC's Civil Works been cured?

The Airport Metro Express Line (AMEL) comprises of 22.91 km length (16 km tunnel + 7 km viaduct), having standard gauge (1435 mm), between New Delhi Railway Station and Dwarka Sector 21. “Viaduct” is the elevated portion resting on pillars (piers) and “Tunnel” section is that below the ground level. DMRC awarded the civil works to IJM Corporation, Berhad & IJM India Infrastructure Ltd, Hyderabad (IJM-IJMII JV) for 7.2 km viaduct portion, Tantia Construction for special spans, and Parswanath Developers for Dhaula Kuan station. Systra was the detailed design consultant for the project, selected on nomination

basis through single tender. The project was required to be completed by September 2010 to cater to the demand for Commonwealth Games (CWG) 2010.

(Please also see our previous article dated 15.11.2023: <https://infralive.com/web/wp-content/uploads/2023/10/Delhi-Airport-Metro-Express-Line-pdf.pdf>)

The commissioning of all railway systems, construction of the maintenance depot at Dwarka (including all civil works) and the operation of the project was awarded to a consortium of Reliance Infrastructure Ltd (R-Infra) and Construcciones Y Auxiliars De Ferrocarriles (CAF S.A., a Spanish company), through

international competitive bidding. On January 1, 2008, DMRC issued the letter of award to the consortium, which thereafter incorporated a special purpose vehicle namely DAMEPL for implementing the Project, with a concession period of 30 years. DAMEPL was responsible for commissioning power supply and traction system, electrical/mechanical systems, tracks, station interiors, signalling system, ventilation and air-conditioning system, fare collection system, platform screen doors, trains etc, and also finishing of DMRC's civil works.

The mandatory “oscillation trials” of the Line were successfully conducted by RDSO at 110% of the designed speed of 120 kmph, in



August 2010, which proved that the railway systems commissioned by DAMEPL met all the specified parameters regarding riding quality and safety. Neither the results of the oscillation trials nor the approval by CMRS raised any issue in regard to the systems installed by DAMEPL. No remarks either were made, with regard to DAMEPL's systems, whether on the viaduct or in the tunnel section.

Discovery of defects in DMRC's civil works and the failure of rail clips:

The operations commenced on February 23, 2011. But, in about a year, serious defects were discovered in DMRC's civil construction (in March-April 2012), which included defective bearings, cracks/ twist in girders, and design issues, as well as failure of rail clips (in December 2011) in the track fastening system (provided by a vendor nominated by DMRC). Almost all bearings and bearing pedestals of the girders either crumbled or got displaced/ distorted beyond permissible limits, thus displacing the girders resting on them and altering the track geometry. Owing to the defects, DAMEPL had to restrict the speed to as low as 25 kmph in the seriously affected sections of the viaduct. The defects in the civil works had a bearing on the safety of operations. Consequently,

DAMEPL put DMRC to notice to investigate and rectify the defects.

Proper inspection of the bearings by DAMEPL was severely constrained on account of the strengthening (jacketing) of piers carried out by DMRC, post construction, which significantly increased the diameter of the piers and presented problem with access to the bearings - apparently carried out after failure of a pier in another section of DMRC's metro-network which had resulted in fatalities. Despite DAMEPL's request to share the reason for such strengthening, DMRC never provided the details to DAMEPL.

From July 8, 2012, the services were suspended. The next day, DAMEPL served a Cure Notice on DMRC to rectify the defects in DMRC's Civil Works within 90 days. When DMRC could not rectify the defects, DAMEPL issued Termination Notice on October 8, 2012, which became effective after 90-days i.e. January 7, 2013. During the period of suspension, repairs were carried out by DMRC with full cooperation from DAMEPL.

MoUD constituted a 2-member Enquiry Committee in July 2012 to inquire into the issue:

The Govt of India (MoUD) formed a 2-member Enquiry Committee on 24.07.2012, comprising of D Diptivilasa (Additional Secretary and CVO, MoUD) and AK Gupta (Additional Member-Works, Railway Board), to inquire into the reasons for the defects leading to the suspension of operations and to fix responsibility for the same. The Committee submitted its report to MoUD on April 1, 2013. Full Report of the Enquiry Committee was posted on InfraLive in Feb 2019: <https://infralive.com/web/wp-content/uploads/2019/02/Report-on-Airport-metro-line-new.pdf>.

The report listed out the following failures:

6.1 Selection of new structural form for a tightly

targeted project: Precast pretensioned U-girders were used for the first time in India along with Precast pier cap for this project. As identified in minutes of tender committee meeting the progress of work required at 400 m/per month of via-duct was nearly twice the progress at 237 m/month achieved for the previous project. Working with a new structural form inducted a pressure which was not conducive for proper execution of the job. Added to that was the problem of non-availability of land, non-mapping of utilities etc. Requisite monitoring for such level of eventualities was not done.

6.2 Selection of IJM-IJMII for the job: This JV had previously not performed well in previous project and bringing them in added to the problems in hand.

6.3 Non-visualization of the total structure and dimensioning it taking into account the precast elements: M/s Systra had the most global view of the proposed structure, tolerances achievable in such situation, in spite of that the detailing of pedestals, bearings and pier cap did not provide for constructional realities, resulting into problems with construction of pedestals, bearings and achieved gaps between girder to girder and between girder and shear key. In fact the ALC having sensed the problem requested IJM-IJMII to provide them with achievable tolerances in placement of girders.

6.4 Global view of the structure: M/s Systra, being the designer had the responsibility of taking the global view. Each of the constructional element had its own tolerances. The structures including pier caps/ pedestals etc.,

need to have been detailed in such a manner that the non-violable dimensions could be maintained. ALC did ask for it from IJM at one time, but it is clear that this was not taken to the required conclusion.

6.5 Non finalization of track form at the earliest:

This could have been finalized at the stage of procuring technical bids from the prospective concessionaires. If the DMRC was so sure of suitability of RHEDA-2000 trackform it could have been prescribed. This resulted in avoidable problems of SIDL, forced compromise with the requirements of RHEDA track, improper management of interface between trackform and structural elements.

6.6 Issue of vague drawings by SYSTRA:

For proper execution of this technical, tightly targeted work it was necessary that the drawings were sufficiently detailed leaving no margin of confusion in the mind of other parties. This difference in perspective was clearly visible during enquiry. The work was considered so technical and perhaps known only to M/s Systra that before obtaining the revised financial bids M/s Systra addressed the prospective tenderers regarding how the work was to be done. It would have been in fitness of things if M/s Systra would have addressed the IJM-IJMII, ALC and DMRC in the beginning regarding how they had visualized the total structures, what drawings will be issued by Systra, what details were required to be worked out by the agency and what special precautions were required to be taken. This is especially relevant because the structure being executed was patented property of M/s Systra and nobody else was likely to have a complete picture of it.

6.7 Improper execution of

work by IJM-IJMII: This could be perhaps taken as most significant failure. M/s IJM-IJMII knowingly bid for the job. They knew their capabilities. They were briefed about the job by M/s Systra before revised financial bid was opened. They had done the site survey before bidding and knew the ground problems, cited by them as justification of poor progress and to some extent about quality of job done. They were instrumental in getting the drawing of bearing arrangement changed to the one with grout. The quality of grout work as also lack of control over its dimensions was the main reason for the failure. The availability of space for execution of job was known to them. They ought to have known the required precautions in placement of grout (like proper formwork and hole for escape of air etc.) They at least ought to have finalized the grout parameters before starting the work as mentioned in ITP. They did not advise the tolerances achievable in placement of precast girders to ALC, when asked. They did not make proper shop drawings nor proper MS. They were equally responsible for the final output along with SYSTRA and ALC and cannot lay the blame on the other parties that they accepted the constructional deviation. They did not follow the finalized MS properly. The list of failures is very long.

6.8 Improper supervision of the job:

ALC was supposed to act as an independent Engineer. They were responsible for scrutiny of scheme before it was implemented. They were required to get the detailed drawings examined. They checked and recommended the design of Systra. They had all the powers to stop work, deny payments, deny completion certificate. They

had the responsibility to fill in the gaps left by other parties. The fact that most of the defects now noticed were observed during construction, non-conformities noted and yet issues were closed, non-conformities allowed to continue puts a large amount of blame on them. They have pleaded that in view of impending CWG, the option of stopping of work was not available. This puts their main capability of being independent to doubt.

6.9 Project management:

The project management ought to have been much tighter. The owner is left at last with the product and is required to see the product is acceptable. All the reports were being received by DMRC and it was the capability of separating the important and urgent from the routine ones, which is somehow found missing.

Further, the Committee identified the following failures on part of DMRC:

- a) Non identification of key critical activities to be watched at DMRC level, they were to be quality with time.
- b) Non identification of post COD regime with Concessionaire properly. Not defining of critical activity of hand over of structures to Concessionaire. Not ensuring finalisation of maintenance plan before COD.
- c) Not ensuring finalisation of adequate organisation structure for maintenance at Concessionaire's level. (Adequacy certificate from Concessionaire was accepted.)
- d) The Project Management could be better.
- e) Having selected precast pretensioned U-girder and precast pier cap for the first time in India, in tight

- schedule, failed to ensure top level monitoring.*
- f) *Having done so, failed to freeze trackform at the earliest (could be done at the time of opening of Concessionaire's technical bid).*
- g) *Award of work to IJM: IJM did not have requisite experience, they had failed to achieve in a lightertime schedule.*
- h) *The initial negotiation identified that ALC were not required to have viaduct expert, by just writing letter availability of viaduct expert of requisite experience for cutting edge technology could not be ensured. Critical DBR and design advice from ALC were overruled. ALC did not have control over critical agency i.e. DDC.*

Investigations relating to track carried out by DMRC from 2015 onwards:

After taking possession of the Project on July 1, 2013, DMRC failed to make any headway to identify the corrective actions necessary for enhancing the peak operating speed of the Line above 80 kmph, for as long as two years. Thereafter, DMRC carried out investigations from 2015 onwards, through the Institute of Sound & Vibration, New Delhi ("ISV"), which carried out trials at different speeds and with different rail pads and clips - both in viaduct section and tunnel section, to understand the changes in behaviour of rail clips. The conclusions in ISV's January 2016 Report were - a sharp increase in strain in rail clips above 100 kmph. The observations seemed to suggest an improvement on changing the rail pads and rail clips. This observation pointed to the incompatibility of track structure with DMRC's Civil Works. The peak operating speed of the trains was restricted to 80 kmph from August 2013 till July

2019 as DMRC could take no material steps to resolve the issues relating to the defects in the civil works.

DMRC also took assistance of ARTS Schilder & Partner GmbH of Austria and Veneklasen Associates India LLP in 2019 for investigating the vibrations in different track forms and suggesting suitable optimized track design. ARTS suggested the use of floating track. However, due to dimensional limitations, it was not possible to implement the same with the existing track on AMEL. The same was adopted with different track form and fastenings in the 2 km extension of AMEL to Dwarka Sector 25, later carried out by DMRC. Such events serve to corroborate that the findings of the Arbitral Tribunal on the seriousness of the defects in the civil works hold.

The present position and the restrictions imposed by CMRS:

As per CMRS' sanction dated March 17, 2023 (which permitted the peak operating speed to be raised to 100 kmph), high acceleration values have been consistently recorded on viaduct section (UP line) at speeds above 100 kmph, and the letter asks for the civil structures to be thoroughly checked and attended, to reduce peak values. From the above, it is clear that the track form suggested and approved by DMRC for AMEL, overruling all the reservations which DAMEPL had, was not suitable and compatible with DMRC's civil structures and the scheduled peak operating speed. CMRS too suspects problems with DMRC's civil structure as brought out in his sanction dated March 17, 2023.

DMRC has changed the rail pads and rail clips in the AMEL to enable the speed to be raised above 100 kmph. However, even after change of rail pads and rail fastening system, the vibration values are beyond the permissible limits (as per ARTS report dated July 17,

2023, which had recommended regular visual inspection of rail fasteners). This means that the AMEL is being operated under limiting conditions, compromising public safety, while the civil structures with the existing track-form are not capable of sustaining the scheduled peak operating speed of 120 kmph, particularly in the viaduct section. This is further evidenced by the fact that the Line had been operated for a very long period (since December 2011 till early 2023) at a peak operating speed not exceeding 100 kmph, which is not what it was constructed for.

Even after so many years and changed rail pads and rail clips, AMEL still does not have complete approval to run at the specified peak operating speed of 120 kmph, and the speed limit of 120 kmph sanctioned by CMRS (on September 6, 2023) after change in rail pads and rail clips excludes a 7 km section of viaduct, where speed exceeding 100 kmph is disallowed. In fact, DMRC voluntarily did not seek increase in speed above 100 kmph for the 7 km section of viaduct (Up Line), when it applied to CMRS on 13.07.2023 for raising the peak operating speed of the Line to 120 kmph. This has been recorded in CMRS' Inspection Report dated August 8, 2023 (see scan at pg 24-25), which was issued before the CMRS sanction dated September 6, 2023. DMRC has deliberately suppressed the fact of the exclusion by CMRS of the 7 km section of the viaduct (Up line) from the speed above 100 kmph, in its press releases dated June 22, 2023 and September 16, 2023.

It may be noted that, while the viaduct had serious problems with the civil structure, the bearings and bearing pedestals, besides insufficient gap between girders at some places, the tunnel had excessive transmission of vibrations and excessive leakage pointing to poor quality of construction and compliance to specifications. Besides, in the extension of AMEL by 2 km, carried out later by DMRC,



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GOVERNMENT OF INDIA
MINISTRY OF CIVIL AVIATION
(COMMISSION OF RAILWAY SAFETY)



Commissioner of Metro Railway Safety,
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Date: 08.08.2023

No. Q/13/12/DMRC/CMRS/2019/12.6

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Sub: Report on Inspection of Airport Metro Express Line (AMEL) of DMRC between New Delhi to Dwarka Sector-21 for raising the sectional speed from 110 kmph to 120 kmph.

- Sanction for raising of speed of Airport Metro Express Line (AMEL) of DMRC to 110 kmph was accorded by CMRS vide letter no. Q/13/12/DMRC/CMRS/2019/75 dated 16.06.2023.
- DMRC has implemented the above sanction and raised the speed of Airport Metro Express Line from 22.06.2023.
- Further, DMRC vide letter no. DMRC/20/IV-410/2022 dated 13.07.2023 has approached this office for raising of sectional speed of Airport Metro Express Line (AMEL) of DMRC between New Delhi to Dwarka Sector-21 for raising the sectional speed from 110 kmph to 120 kmph excluding UP line CH 6494.05 m to CH 13532.24 m (7.038 km) on viaduct.
- Inspection of Airport Metro Express Line (AMEL) of DMRC between New Delhi to Dwarka Sector-21 for raising the sectional speed from 110 kmph to 120 kmph was conducted on intervening night of 17th & 18th of July 2023.
- During the inspection, a test run was conducted on train set TS-04 operated by Shri Jayant Kumar (Emp.ID-80645). The train trial followed the schedule below:

Departure		Arrival	
Station	Time	Station	Time
New Delhi Metro station	0100 Hrs	Dwarka Sec-21 Metro Station	0116 Hrs
Dwarka Sec-21 Metro Station	0127 Hrs	New Delhi Metro station	0143 Hrs

The test run of the train was found satisfactory.

- At the same time, OMS recording was carried out on the train. The equipment was installed in the first coach of the train, facing the moving direction, during both runs.

The OMS measurement details are presented in the table below:

SN.	Date	Speed	Section	Line	Run no.	Maximum values of peak during trial	Total nos. of peaks $\geq 0.15g$	Maximum value of Riding Index (R.I.) during trail
1.	17/18.07.2023	120 kmph except viaduct section in UP line b/w CH 6494.05m to 13532.24 m where maximum speed reached to 95 kmph	New Delhi to Dwarka Sec-21	DN	361	Nil Nil	Nil Nil	2.93 2.59
2.	Dwarka Sec-21 to New Delhi		UP	362	Nil Nil	Nil Nil	2.89 2.38	

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7. After the train trial run, discussion was carried out with DMRC officials on document submitted such as Technical report of M/s ARTS dated 12.07.2023, OMS report of trials conducted by DMRC on intervening night of 12th & 13th of July 2023 and other documents.
8. It is noted that increase in vibration levels from 90 to 120 kmph was more than the adjustment values from FTA and CT-38.
9. Further after the discussion, it was concluded that DMRC shall extend the trials run at 120 kmph and submit the updated Technical report accordingly, also DMRC shall submit the inspection record of all department viz. Civil, Track, Rolling stock, traction etc. for the period from the date of raising of speed to 110 kmph till date, along with Joint Safety certificate, CEO certificate and fitness certificate from all department.


 (Janak Kumar Garg)

Commissioner of Metro Railway Safety
New Delhi

its consultant has not advised use of the same (RHEDA 2000) track form, which further points to problems with the track form suggested and approved by DMRC.

Avoiding the inconvenient truths:

In all the investigations carried out by DMRC, any design or compatibility issues relating to DMRC's civil structures were surprisingly excluded. The main focus was to suggest changes in track structure to somehow enable operation of AMEL at the scheduled peak operating speed of 120 kmph.

ISV had pointed out abnormal behaviour beyond 100 kmph, confirming the suspicion that DMRC's civil structure was not compatible with the specified track-form and the rolling stock (that is, the trains).

DMRC has from July 2013 till date, despite suffering an adverse award and later the judgement dated September 9, 2021 from the Supreme Court, avoided any public disclosure of the facts, as revealed by its investigations, in regard to the issues which have prevented DMRC from increasing the peak

operating speed to the scheduled peak operating speed.

Root cause of the issues:

DAMEPL is a high speed metro line with very different technical characteristics compared to other conventional lines of DMRC. However, no prior studies were carried out by DMRC in regard to compatibility of track structure with the specified parameters of trains for high speed running. It may be noted that the maximum speed achieved by trains on DMRC's other lines is of the order of 80 kmph and that too for a very short duration, unlike AMEL where, due to significantly longer station spacing and higher specified peak operating speed, trains run for considerable time at peak operating speed. The light twin U-girder construction at such high speed was also untried.

On top of this, DMRC rejected all track forms suggested by DAMEPL and pressurized DAMEPL to zero down only on one type of track form – R H E D A 2 0 0 0, despite DAMEPL's serious technical objections in accommodating this type of track form due to weight and dimensional constraints of

DMRC's civil structures. This called for several modifications in original design of RHEDA 2000, which were unproven yet DMRC had no objection with those and approved the changes in design. Several correspondences with DMRC in this regard, requesting it to at least reconsider their decision for the viaduct section, proved unsuccessful. This, as seen later, was the source of all the technical problems and also led to significant delays in track work.

Three systems which are directly involved in safety of train running are civil structures (of viaduct and tunnel), the track and the trains. The possible reasons, for the problems being encountered, can therefore be any one or more of the following:

- (i) **Defects in viaduct structures:** The defects in viaduct structure and consequent influence on track are well documented in investigation reports following failure of viaduct bearings and subsequent rectification by DMRC. Defects in civil structure of viaduct directly influence the track performance and this aspect has even now not been

sufficiently investigated by DMRC, nor the reasons are disclosed as to why DMRC undertook strengthening of piers, without providing details of strengthening to DAMEPL, which was to operate the AMEL. CMRS has also pointed to the possible problem in viaduct structure and has withheld approval for even 110 kmph for a 7 km section of viaduct (UP line) even after so many years of operations.

(ii) **Incompatibility of civil structures, track and trains:**

DAMEPL was only responsible to provide track and trains as specified. No report has so far brought out any issue with the trains. DMRC had itself pushed for RHEDA 2000 as the track form. In spite of DAMEPL's several technical reservations in implementing RHEDA 2000, DMRC insisted and finally a much modified version of RHEDA 2000 was implemented as approved by DMRC. Ironically, the terms of reference of none of the investigations includes this aspect. The incompatibility of RHEDA 2000, as adopted in AMEL, with DMRC's civil structures therefore cannot be ruled out. The "ringing" of rail clips and excessive vibration near 100 kmph speed also points towards the tendency of resonance. This aspect has also not been investigated thoroughly.

(iii) **Defects in tunnel structure:**

This aspect including any settlement has not been investigated in any of the reports and therefore cannot be ruled out. It may be noted that the seepage in tunnel was reported to DMRC as excessive and beyond the specified limits, during the initial period of operations itself. This was first denied by DMRC and later accepted when joint measurements were undertaken. The bored tunnel structure also

gave way to water gushing out at one place after the line was put in operation, which had to be plugged on emergency basis by DMRC. This too points out towards poor quality of construction. Moreover, several nearby buildings near the tunnel section complained of excessive vibrations during the early phase of operations. Therefore, shortcomings in tunnel structure also cannot be ruled out.

(iv) **Insufficient investigation by DMRC prior to specifying technical parameters:**

The technical specification as contained in the Concession Agreement in regard to civil structures, track and trains generally follow the same pattern as in case of DMRC's other lines, which have lower speeds. No investigation in regard to possible resonance tendencies, noise, vibrations or oscillations was undertaken to ensure that the systems are compatible with each other. The possibility of incompatibility therefore cannot be ruled out.

(v) **Poor quality of rail clips including geometry and metallurgy:**

Some doubts were raised in regard to possible poor quality of rail clips. This was also made much of by DMRC, in its pleadings before the Delhi High Court as well as the Supreme Court, in DMRC's challenge to the arbitral award dated May 11, 2017. If we assume that rail clips were of poor quality, their replacement should have mitigated the issue. However, it was seen that even replacement by similar good clips also did not help. Moreover, had this been the issue, DMRC would have to just replace all the clips and the problem would have been solved. The problem persisted even after the replacement of clips, especially in the viaduct section, proving that this is not the root cause.

Conclusions:

While it is possible to make changes in track and track fittings, it is practically impossible to make any changes in trains or civil structures, once they are constructed. Since measurements taken in trains during oscillation trials prove that train systems and suspension are behaving as expected, the only remaining system identifiable for possible source of failures is the civil structure. It may be noted that no direct measurement on civil structures, except deflection of viaduct girders, has been carried out and no investigation has so far covered issues relating to civil structures or incompatibility of civil structures, track and rolling stock.

It is amply clear that the civil structures were specified, designed and constructed without proper investigations. The poor quality of construction of viaduct and tunnel is apparent from failure of bearings and bearing pedestals in case of viaduct and excessive leakage in tunnel sections, which is also supported by the fact that DMRC took action against its consultant (ALC, whose performance security of Rs 5.80 crores was forfeited) as well as its civil contractor (IJM-IJMII JV, who was disqualified from DMRC's Phase III tenders) pursuant to the report of the Enquiry Committee, as admitted by Ministry of Urban Development in reply to a Parliament Question on December 5, 2013.

The issue to be addressed is much more than the defects in the civil works, as DMRC needs to confirm the compatibility of the rail systems with the civil works, which are adversely impacted by design issues. The issues are yet to be closed as of December 2023, despite DMRC trying to somehow ensure that the remaining 7 km of the viaduct (UP line) gets the green signal from CMRS to achieve the speed of 120 kmph. It is DMRC's responsibility to ensure that the train operations are safe for the public as well as for the project assets.