**IMPROVEMENT OF MAINTENANCE FACILITIES OF MATADI BRIDGE**

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**ABSTRACT** The Matadi Bridge, a suspension bridge in Democratic Republic of Congo, was completed in May 1983 by the Japanese ODA. The inspection facilities such as the under girder inspection vehicles, the inside girder inspection vehicles, are equipped on this bridge. As the bridge have been opened to the public for nearly 30 years, these maintenance vehicles need to be improved because some deteriorations and the consequent problems have been found and reported by OEBK which maintains the bridge. JICA(Japan International Cooperation Agency) dispatched experts to solve these problems and repaired the inspection vehicles at the site in cooperation with OEBK. This paper reports the improvement activities done by JICA Study Team.

Key Words : 検査車、改良、吊橋、マタディ、Maintenance facilities, Inspection vehicles, Improvement, Suspension Bridge, Matadi.

1. BACKGROUND

The Matadi Bridge, a suspension bridge with the span arrangement of 101+520+101=722 m and a road/railway combined bridge in Democratic Republic of Congo (DRC hereinafter), was constructed by the Japanese ODA and completed in May 1983 (Photo. 1 & Fig.1). From 20th to 25th of August 2009, engineers of IHI (Ishikawajima-Harima Heavy Industries) visited and checked the bridge by their own cost because IHI was the main contractor of this bridge and engineers of OEBK and IHI knew each other well. Based on their report, two short term JICA experts from the Honshu-Shikoku Bridge Expressway Company were dispatched from May 28th to June 5th 2010, to examine the maintenance facilities of the bridge and the main cables. From June 17th to July 13th 2011, a preliminary JICA study to plan a main cable opening inspection and to investigate the maintenance facilities was performed. From June 10th to 24th 2012, the maintenance facilities study team was sent to the site and planned the improvement of the facilities. At the same time, from June 6th to 28th 2012, a cable study team was sent to the site and two study teams cooperated together.

The maintenance equipment of the Matadi Bridge is shown in Fig.2. Two under girder inspection vehicles are equipped at the center span and they are shown in Fig.1, Photo.2 & 3. These under girder inspection vehicles cannot move to the side spans. Directly under the orthotropic steel deck of the bridge, two inside girder inspection vehicles are equipped as shown in Fig.1 and Photo.4. Both end sections of the floor can be extended and contracted. When the vehicle is moving under the bridge deck, the end sections need to be

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The preliminary JICA study in 2011 pointed out the following requests from OEBK.

1. On the side spans, there are no under girder inspection vehicles from the beginning. The inspection vehicles on the side spans are requested. At the center span, there are a few places of the rails where it is difficult for the under girder inspection vehicles to pass through. It is requested to solve these problems. Some hand driving gears of the inspection vehicles are also broken and the repair of them are requested. On both ends of the under girder inspection vehicles, manual elevating platforms are equipped. Due to the deterioration over time, these platforms do not function properly. It is requested to repair or renew them.

2. One of the hand driving gears of the inside girder inspection vehicles is inclined and the repair is requested. At one place of the rail of the inspection vehicle, there is about 2mm rail level difference and it is difficult for the vehicles to pass over this difference. There is one more similar place, too. These differences need to be repaired.

3. The tower inspection vehicle was functioning well until 2010. But when the vehicle was left on the tower pier, a control panel was stolen. Since then the vehicle could not be used. New vehicles are requested.

4. The expansion joints need to be maintained regularly but there are no access scaffoldings. New manufactured in Japan vehicles are requested.
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(4). The expansion joints need to be maintained regularly but there are no access scaffoldings. New
scaffolding are requested.

(5) There are one truck with crane and one aerial working platform truck. As they have been used for nearly 30 years, they are already deteriorated considerably and the replacement is requested. These facts were again confirmed by the maintenance facilities study team in 2012 and the improvement plans were prepared in a report. Based on this report, materials for the improvement of maintenance facilities and trucks were prepared and sent to DRC. In 2014, from June 9th to August 7th, the maintenance facilities installation team was sent to the site and improved the various maintenance facilities in cooperation with OEBK engineers. This paper reports the improvement activities stated above.

2. UNDERSTANDING OF PROBLEMS AND SOLUTION PLAN

The problems of the maintenance facilities are introduced in Sec. 1. In this section, the problems are explained in detail and the countermeasures for these problems are proposed.

2.1 Under Girder Inspection Vehicle

No under girder inspection vehicles are equipped on the side spans from the beginning as shown in Photo 7. But the connection pieces for the brackets to fix rails exist. The side span vehicles may have been omitted to reduce the initial cost with the reason that the side span could be maintained from the land [1]. As shown in Fig.1, the side spans are over the land but it is very high from the ground. At the center span, there are two inspection vehicles and OEBK utilizes them for the
daily maintenance works and used them for the repainting works from 2003 to 2009 [2]. On the side spans, there are no vehicles and the girder was repainted in a manner shown in Photo 8. As this work becomes much safer with the side span inspection vehicles, OEBK strongly requests the installation of vehicles on the side spans. Another problem of the center span inspection vehicles is as follows; One inspection vehicle is supported by four pillars hung from the rails fixed on the truss girder. (Photo 2 & 9) Between pillars and rails, hand driving gears are installed and the vehicle can be moved manually. Moving the vehicle requires considerable labor, as shown in Photo 10. Many driving gears are already broken after about 30 years of service (Photo 11). Therefore these driving gears need to be replaced by new ones. Another problem is that as the rail is not straight (Photo 12), wheels of driving gears sometimes detach from the rail and the vehicle cannot move. This can be confirmed from the rail surface. As shown in Photo 13, a painted surface remains on the rail where the driving wheel detaches and no friction occurs. But with some frictions, the paint is removed and the rusty rail surface appears as shown on the left of the rail in Photo 13. When the friction is weak and the inspection vehicle cannot be moved, a technician will push the vehicle pusher by Technician holding lower truss chord.

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Photo 11 Healthy driving gear, left and gear without chain, right

Photo 12 Rail bent

Rusty surface

Paint

Photo 13 Rail with no friction on right, paint remains and rail with some friction on left, rusty rail surface.

Photo 14 Vehicle pushed by Technician holding lower truss chord.

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Fig. 5 Inclination of driving gear due to difference of two distances, \( \delta r \) & \( \delta p \)

Fig. 6 Partial Enlargement of Fig. 5 & Detachment of driving wheel from rail

Fig. 7 Improvement of driving gear, both sided driving wheels
Another problem is the rail level difference which can be explained as follows; The width of the vehicle has a fixed length. But the distance between two rails vary as shown in Photo.12. If the distance becomes narrower, the driving gear becomes inclined as there is a pin below the gear to allow the rotation. Although this inclination may be small, the friction between the rail and the wheel may become weaker and the wheel may run idle. This situation is explained in Fig.5 & 6. Another possibility is that even though two distances are the same \( r = l \), if rails are fixed in the inclined position, the same situation will appear. If both wheels of the driving gear can be driven, then this problem can be solved. (Fig.7) These original driving gears were the products of KITO Corporation, Japan. The possibility of the improvement of both sided driving wheels was inquired to the present KITO Corporation. Their answer was that it was possible although a special order was needed. It was decided to adopt this improvement. As the original gears were discontinued, it was decided to introduce new gears including pillars.

OEBK requests to electrify the inspection vehicles because it is laborious to drive the vehicles manually and also they know the electrified inspection vehicles of Japan, but unfortunately this request is rejected because it is difficult to maintain electrified machines [3] and it is better to avoid the theft.

Another problem is the level difference of the rails as
shown in Photo.15. The difference is small and about 2mm or less. If the vehicles are electrified, this difference cannot be a problem. But the vehicle is manually driven, sometimes it is stopped at this difference. Then technicians drive back the vehicle and try to pass through the difference with the momentum. There are at least three places of this difference. Then it is decided to grind the surface to erase the difference. The last problem is about the elevating platforms placed on both ends of the under girder inspection vehicle. (Photo.3) According to OEBK, this platform can be elevated but cannot be stopped properly and sometimes the platform slips downward. As these platforms are too old and exceed the service life, it is decided to replace them by new equivalent ones.

2.2 Inside Girder Inspection Vehicle

The inside girder inspection vehicle is shown in Photo.4. The problems of the inside girder inspection vehicles are as follows; The driving gears of these inside girder inspection vehicles are already worn out in the same way as those of the under girder inspection vehicles. One of them is even inclined as shown in Photo.16. These driving gears need to be replaced by new ones. For the inside inspection vehicles, the problem of running idle of driving wheels does not exist. Another problem is the rail level difference shown in Photo.17, which is the same problem as that found on the under girder inspection vehicles. Two places of this difference are confirmed. To solve the problem, the differences will be ground, too. On the side spans, there is 1% longitudinal gradient as shown in Fig.1. When the inside girder inspection vehicle climbs this 1% slope, technicians utilize the chains to rotate the driving wheels and this is a laborious work. (Photo.18) But when the vehicle descends down this 1% slope, technicians push forward the vehicle by holding the steel truss members. (Photo.19) It is much faster and easier to push the vehicle by this way than to rotate the driving wheels by chains, because of the gravity. When engineers and technicians of OEBK inspect the bridge by this vehicle from the tower to the anchorage direction and the work ending time comes, they stop the vehicle near the anchorage, extend the vehicle floor to its maximum and climb up to the bridge deck level as shown in Photo.20 with the help of the connection piece of the truss chord and their safety belts. This is because it is too laborious to drive back the vehicle to the tower position, where there is a ladder. As this may be a dangerous practice, one of the authors proposed to install a new ladder near the anchorage, which is the same type of ladder shown in Photo.21. At the center span, there are three ladders at every quarter span length, i.e. 1/4 point, 1/2 point and 3/4 point[1].

2.3 Tower Inspection Vehicle

The tower inspection vehicles were working well until 2011, when the control panel was stolen. The tower inspection vehicle was left overnight on the top of the tower pier which was about 10m high from the ground and the access to this place was very difficult. The commercially available suspended working platforms were adopted for the original tower inspection vehicles of the Matadi Bridge. As almost 30 years has passed and the repair of the original tower inspection vehicles is impossible. But the platforms with the equivalent performance are available so that it is decided to replace the old ones by new ones.

2.4 Cable Inspection Vehicle

When the bridge was completed, one cable inspection vehicle was prepared. (Photo.5) But OEBK judged that one inspection vehicle was inadequate and they asked one institute in Matadi to make one more cable
creeping out. As it is not easy to change the structure to fix the rails more firmly and OEBK always inspects the condition and pushes back the rails regularly, there are no serious problems so far. It is decided to add the scaffolding only.

2.6 Truck & Aerial Working Platform, etc.

At present, OEBK has one 4t truck with crane, one aerial working platform truck, one 10t truck crane and one backhoe loader. 4t Truck is shown in Photo.24. This truck has run already 1,130,000km (far more than 100,000km) and is worn out. This needs to be renewed. The aerial working platform truck is shown in Photo.25. This has a performance of 200kg × 24m. This truck is used for the exchange of the electric bulbs of lighting poles and the inspection of the main cables. This truck has run more than 730,000 km. The platform can be extended but it cannot be rotated because of the malfunction. This truck also needs to be replaced by the equivalent machine.

The 10t truck crane is shown in Photo.26. This is a large truck crane and used for the time of the construction. Therefore for the maintenance activities, this size of large truck crane may not be needed. OEBK uses this truck crane to load the cable inspection vehicles on the cables. The outriggers of this crane do not work properly due to the deterioration.

The backhoe loader is shown in Photo.27. This loader is used for the maintenance of road sections. When this photo was taken, this machine was out of order because of the deterioration of the hydraulic packings. But later this machine was repaired by OEBK and they utilize this machine. This machine is very useful for the maintenance of earthwork sections. But this may not be needed for the maintenance of bridge proper and it is decided not to renew. This is a product of KOMA TSU Ltd. Japan. In Kinshasa there is a branch of one European Company which deals with KOMA TSU products. There are many kinds of metal mines in DRC and many KOMA TSU products are utilized in DRC. According to this branch, they maintain even older inspection vehicle on the model of the Japanese vehicle, but with the improvement of the slightly lower platform to facilitate the painting of the cable bottoms. (Photo.22) This shows the enthusiasm and the dedication of OEBK for the maintenance. In this report, there are no improvements for these vehicles. But for the installation of the dry air injection system for the cables, it is planned to add two more cable inspection vehicles to facilitate the work. But this may be reported separately.

2.5 Scaffolding for Expansion Joint

The finger expansion joints are installed between the anchorages and the ends of the truss girder. Under the expansion joint, there are several supporting rails. One problem is that some supporting rails are creeping out regularly so that OEBK is continuously monitoring these rails and pushes back these rails. (Photo.23) To monitor and to push back rails, a scaffolding is indispensable. They manage to reach the place directly under the expansion joint from the inside girder inspection vehicle at present. OEBK requests the permanent scaffolding. The rails are fixed on the abutment with the structure shown in Fig.8. The rubber plates under the rails may have been deteriorated and the rails may not be fixed firmly. This may be the reason why the rails keep...
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One example of a truck with crane which satisfies the above specification is ZE505L, a product of TADANO Ltd. When 15.69m boom is used, the capacity of lifting weight is 530kg. The relationship of capacity of ZE505L and the cable inspection vehicle is shown in Fig.9. A truck with crane which has an equivalent capacity to ZE505L is needed.

3. REPAIR AND INSTALLATION AT SITE

The repair and installation of the maintenance facilities stated in Sec.2 was executed at the site. For this work, the donated truck with crane and the aerial working platform truck were fully utilized together with the OEBK’s 10t truck crane. The donated 10t truck with crane and the aerial working platform truck are shown in Photo.30 & 31.

3.1 Side Span Under Girder Inspection Vehicles

First rail brackets and rails were installed as shown in Photo.32. Then the driving gears were set on the rail and the inspection vehicle which had been fabricated beneath the girder beforehand, was lifted by OEBK’s 10t truck crane and the new 10t truck with crane as shown in Photo.33. The driving gears and the pillars of the inspection vehicle were connected at the site and the installation of the vehicle was finished. (Photo.34) Afterwards the smooth movement of both side span inspection vehicles were confirmed.

The new elevating platforms were installed on both ends of the under girder inspection vehicles. (Photo.35) This platform was equipped with casters so that it could move to anywhere and could be fixed by outriggers when it stopped. But when the platform was extended, OEBK technicians complained that it was unstable and it was decided to fix the platform by welding on the vehicle. There were pedestals for the former elevating platform and the outriggers of the new platform were welded on these pedestals. Due to this alignment, the distance between the platform and the side surface of the truss girder became a little too far as shown in Photo.36.

In the beginning, the platforms were planned to be installed perpendicular to the truss girder unlike the vehicles of OEBK and they can repair the backhoe loader to the complete condition. This information is transmitted to OEBK and OEBK can repair the backhoe loader completely if they so wish.

As it is decided not to replace 10t truck crane and this 10t truck crane is no longer reliable due to the deterioration, the size of the truck with crane which can load the cable inspection vehicles on the cables needs to be decided. The loading of the cable inspection vehicles is investigated. At first, it was thought that the loading of vehicles on the cable was easy at the center of the center span or near the anchorages where the cables were the lowest. But the situation was a little complicated because there were lighting poles just beside the main cables and the inspection vehicles could not pass these poles.

The situation is shown in Photo.28 & 29. As shown in Photo.28, the lighting pole is quite close to the main cable, the inspection vehicles need to be placed beyond this pole. The pole is 8.0m high. As shown in Photo.29, the vehicle needs to be placed where the hand rope height is about 11.1m. The height and the weight of the vehicle manufactured in Japan is about 2.5m and 332kg respectively from the document of the construction. The height of the vehicle manufactured by OEBK is slightly higher and assumed to be about 3.0m. The weight can be assumed to be 350kg. From these data, the necessary capacity is as follows;

1. Lifting Height 11.1m + 3.0m + 1.0m = 15.1m where 1m is the length of the sling.
2. Lifting Weight 350kg
3. Operating radius 5m
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present parallel position to the girder shown in Photo.36. But due to the limitation of the space of the under girder inspection vehicle, the perpendicular position was impossible. It is not difficult to place the platform closer to the girder and also it is not necessary to weld the outriggers on the former pedestals. It is hoped that OEBK would find the desirable position and re-weld the outriggers on the vehicle.

3.2 Replacement of Driving Gears of Vehicles

The driving gears of the inside inspection vehicles and those of the center span under girder inspection vehicles needed to be replaced. First the inspection vehicle was lifted upward slightly by chain blocks, which were newly brought to the site from Japan, to release the stress of the driving gears. (Photo.37) Then the old driving gears and pillars were replaced by new ones. (Photo.38)

The rail level differences of both the inside girder inspection vehicles and the under girder inspection vehicles were ground and flattened to solve the problems. After the replacement of the driving gears and the repair of rail level differences, the inspection vehicles were tested to confirm the smooth movement.

3.3 Tower Inspection Vehicle

Two new tower inspection vehicles were prepared to replace old ones. The new tower inspection vehicles were transported to the site and lifted on the tower pier as shown in Photo.39. The new wire ropes were arranged on the tower and then the vehicles were tested and confirmed their maneuverability.

3.4 Installation of New Ladders

Near two anchorages and at the end of side span truss girders, new ladders were installed. (Photo.40) After the installation, the performance to facilitate the movement from the bridge deck to the inside girder inspection vehicle was confirmed. It became much easier to reach the inside girder inspection vehicle from the deck.

3.5 Scaffolding for Expansion Joint

Before the installation of the permanent scaffolding
under the expansion joint, the concrete surface of the anchorage, on which the scaffolding was planned to be installed, was inspected. But the rock pockets and the repaired surfaces were found and it was judged not to install the permanent scaffolding on this surface. (Photo.41) Another fact was that the permanent scaffolding was designed so as not to interfere with the railway clearance and the height from the floor to the expansion joint was only 70cm. Then it was judged that it was better to install a temporary scaffolding which had enough height and interfered with the railway clearance because there were a low possibility of usage of the railway space and even if the railway space would be used the removal of the temporary scaffolding could be quite easy. (Photo.42)

4. CONCLUSIONS
The Matadi Bridge is well maintained by OEBK, partly because the maintenance vehicles work well. This is partly because the vehicles are not electrified, the maintenance of these vehicles are comparatively easy and the possibility of theft of unelectrified parts is low. But after about 30 years from the completion, some defects and deteriorations of the maintenance vehicles were reported by OEBK and OEBK had requested Japanese Government to repair and improve them as the mechanical parts could not be repaired by themselves. The defects and the deteriorations were repaired as reported in this paper. The authors hope that these improvements would contribute to the easier maintenance works of OEBK and consequently to the maintenance of the Matadi Bridge for the next 10 or 20 years. If the Matadi Bridge were in Japan, each defect would have been repaired much earlier soon after the detection. For the Matadi Bridge, 30 years of defects and the deteriorations were repaired at once.

As the mechanical parts cannot be obtained in DRC, even from now on, a continuous support from Japan to OEBK may be needed.

One of the biggest problems is the maintenance of trucks. There are no branches of Japanese Truck makers in DRC and the spare parts need to be procured from, for example, South Africa. For the 10t truck with crane and the aerial working platform truck, the one year warranty and the 5 years availability of spare parts are guaranteed by the contract of this time, at least. But OEBK may utilize these trucks far beyond this period as it can be seen for former trucks. Then it is feared that the availability of spare parts may become difficult.

It would be a great pleasure for the authors if this paper would be of some help for the next improvement of the inspection facilities of the Matadi Bridge and also for the maintenance of other bridges in the developing countries.

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