REAAA Technical Report

Development of Pavement Manuals for Community Roads in Myanmar

Working Group/Review Panel on QA of Pavement Structures
on behalf of REAAA Pavement Technology Committee

Kazunari Hirakawa

REAAA Technical Report TC-12

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DEVELOPMENT OF PAVEMENT MANUALS FOR COMMUNITY ROADS IN MYANMAR

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REAAA Profile

REAAA is the Road Engineering Association of Asia and Australasia. The association promotes the science and practice of road engineering and related professions in the Asia-Pacific region through the development of professional and commercial links within and between countries in the region. REAAA Chapters have been set up in Australia, Brunei, Korea, Malaysia, New Zealand and the Philippines. REAAA is also active in Indonesia, Japan, Singapore, Taiwan and Thailand.

REAAA was established in June 1973 with a permanent secretariat in Malaysia. Currently there are more than 1,200 members in 23 countries. It holds regular events including two Governing Council meetings each year, business forums, a quadrennial international conference, technical visits and study tours, trade exhibitions, seminars, forums and workshops. It also publishes a Journal and a Newsletter. The most recent initiative is a series of technical reports addressing issues of concern in the region.

REAAA Technical Reports

This is the twelfth in the series of Technical Reports since the first report was published in 2008. The following Technical Reports have been published to date.

TC-1 Guide to privatisation of expressways and highways

TC-2 Disaster risk management

TC-3 Efficient operation of the road network

TC-4 Road safety – make it happen

TC-5 Pavement durability

TC-6 Guide to the public-private partnership of road and highway projects

TC-7 Incorporating Japanese pavement design practice for a community road in Mongolia

TC-8 Pavement maintenance and rehabilitation practices

TC-9 Compendium on pavement recycling

TC-10 Report on FEHRL scanning tour to South Korea and Japan: infrastructure resilience

TC-11 Compendium on pavement structural design and rehabilitation methods adopted by member countries

TC-12 Development of pavement manuals for community roads in Myanmar

REAAA Technical Sub-Committee: Pavement Technology

The REAAA Pavement Technology Committee (PTC) is one of the three sub-committees reporting to the Technical Committee. It was established at the 108th Governing Council meeting in Brisbane, Australia, in May 2018. The first meeting focussed on the topics to be dealt with by the sub-committee. At the same time, cooperation with, and reference to, the relevant PIARC pavement committee has been maintained so that collaborative activities of mutual interest to both REAAA and PIARC are maintained.

Membership of REAAA Pavement Technology Committee

Including Cooperation with PIARC Committee:
TC.4.1 – Pavements

(New PIARC cycle commenced in October 2019 and will run until October 2022)

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The input from the member countries who responded to the questionnaire and provided additional information is gratefully acknowledged.

SUMMARY

A technical cooperation project with Myanmar commenced in 2011 following a request for assistance from that country. The project was supported by the Japan International Cooperation Agency (JICA) and the Japan Road Association (JRA). The project had two phases, one from June 2012 to September 2014 and the other from April 2016 to December 2019. A technical committee was set up in each country and four joint meetings of the both technical committees were conducted, including two meetings in Japan where key Myanmar members were invited to inspect examples of pavement technologies in use in Japan.

Two manuals and a handbook on pavements were produced. In the preparation of the documents, field tests were conducted to consider local conditions. The main author of this report was a member of the technical committee in Japan and also participated in the joint meetings.

The outputs of the project were as follows;

- A *Manual on community-inclusive type pavement works for low-traffic-volume roads*, which was produced during Phase 1 of the project in 2014.
- A *Manual on pavement works using hot mix asphalt and ready-mixed concrete*, which was compiled during Phase 2 of the project in 2018.
- A *Handbook on pavement works*, which was completed in 2019.

The report describes the technical issues discussed at the committee meetings and the problems faced in the field during the project, which were mostly related to the contents of the two manuals.

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1 INTRODUCTION

Road pavements in Asia in urban areas or on trunk highways connecting large cities have largely been developed. In contrast, however, roads in rural areas, including those connecting cities with villages and those within local communities where traffic is light, are often unpaved.

Few countries have yet fully established technical standards of pavement for these lightly-trafficked roads. Practice is generally to adopt the standards introduced by colonial governments or those with a powerful economy.

Especially in rural areas where poverty is widespread, labour-intensive infrastructure development, including community-participation, is important in terms of securing employment. Therefore, promoting the development of lightly-trafficked roads that can be constructed and maintained by the local community will result in an improvement of the quality of life of local communities in poor areas. It is also important to develop high-quality pavements for trunk roads which link these roads.

Yano & Onon (2015) reported a successful example of technology transfer of the Japanese penetration macadam method, which has become a community-inclusive standard pavement in Mongolia. This report also addresses the results of technology transfer of the same type of pavement construction in Myanmar during Phase 1 of the project, which was implemented in response to a request by the government of Myanmar. This report also discusses the issues that were addressed during the subsequent technology transfer of high-grade pavements as Phase 2 of the project.

Yano & Onon (2015) concluded that the penetration macadam method may contribute to road improvement in rural areas in developing countries in Asia, regardless of whether they were located in cold, warm or humid regions. However, there remained a concern that the success or failure of a high-grade pavement largely depends on the experience of the road agencies in the management of quality control and construction technology. As this is an issue common to developing nations in Asia, the findings are relevant to the future growth of other Asian countries.

2 BACKGROUND AND INITIATION OF PROJECT

Ayeyarwady, a region in Myanmar and the target area of this project, is a rice producing area. However, sufficient infrastructure such as roads had not been adequately developed, and it was difficult to transport rice and other agricultural crops. In addition, those of working age who lived in the area were moving to Yangon in search of employment opportunities, which further made the region poorer.

To add to the problems, Cyclone Nargis struck the area in May 2008, which resulted in 2.4 million casualties, including 14,000 killed and missing. In response to this situation, the Myanmar government launched an emergency road project to construct 11 new routes and 840 km of road in the Ayeyarwady region. However, since there were no technical standards for labor-intensive, community-based road construction, it was difficult to carry out intensive construction and the project was not properly implemented.

In response to these problems, Japan Infrastructure Partners, in cooperation with the Japan Road Association, saw the need to prepare a manual that would contribute to community-inclusive road development in Myanmar. The decision was based on the successful technical transfer of Japanese penetration macadam method into a local community in Mongolia in 2006 Yano & Onon (2015). Following the preparation of the manual, two technical manuals for asphalt pavements and cement-concrete pavements were compiled to help meet the future needs of the country. These manuals were later combined into one manual.

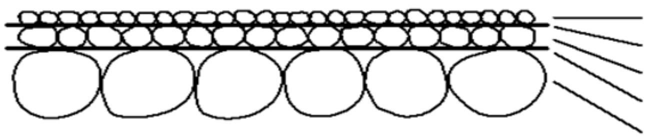
The author had participated in the project in Mongolia as one of the technical committee members of the Japan Road Association since 2013. He has also been engaged in the planning of trial construction sites, the design of the sections, technical guidance, and the creation of associated manuals. The activities conducted to date are reported in the following section of this report.

3 PHASE 1 – PENETRATION MACADAM PAVEMENT

3.1 Background

Most of the road projects in rural areas in Myanmar are controlled directly by the Department of Public Works or, currently, the Ministry of Construction (MOC). Urban streets are surfaced with cement-concrete, while the country's conventional penetration macadam method is usually applied on suburban roads.

Figure 1 illustrates the cross-section adopted, and the materials used in Myanmar's conventional macadam methodology, to which the people of Myanmar are well accustomed. Whilst the method is popular, it differs a great deal from the penetration macadam pavement constructed in Japan. A typical Japanese penetration macadam pavement is shown in Figure 2.



* Not specified.

Figure 1: Cross-section of typical penetration macadam pavement used in Myanmar

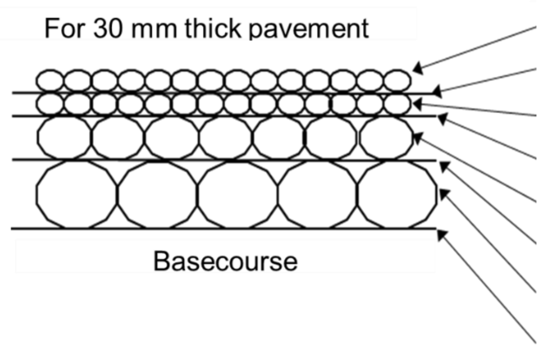


Figure 2: Cross-section of Japanese penetration macadam pavement

3.1.1 Conditions

Road roughness

In Myanmar's rural areas, gravel roads consist of a lower base layer, above which an upper granular base layer is paved, followed by the penetration macadam. However, if the existing gravel base is used as the surface (i.e. it is unsealed), then final road surface will eventually become so rough that vehicles can only travel at about 20 km/h and it is difficult to avoid irregularities on the pavement surface.

*Material*s

The key aggregates are not usually plant-mixed crushed rock, but more often natural stone which is laboriously crushed by using a hammer at the job site. This manual operation results in the production of aggregates larger than the 50-76.5 mm specified in the specification, with material as large as 100-150 mm frequently produced.

Ground conditions

Swampy areas are widespread, so early distress of the pavement can be observed all the year round on rural roads, where conventionally-specified structures are seemingly not suited. During the rainy season, edge shoulders are often eroded due to the weakened ground (see Figure 3). The narrowed lane width inevitably makes it very difficult, if not impossible, for vehicles to pass each other (see Figure 4).

Figure 3: Normal condition of a rural road

Figure 4: Damaged roads in rainy season (2010)

Field performance

Straight asphalt is specified for bonding aggregates, but a prime coat is not applied on to the basecourse as an impermeable layer. This often results in weakened pavements and the loss of surface aggregates under loading. This is one of the causes of early distress.

Given these conditions, and in order to demonstrate the Japanese penetration macadam method, a trial construction was carried out which had the following objectives and tasks:

- demonstrate the importance of an initial survey to ensure that the road roughness after construction was acceptable and that the materials preparation process was sufficient to ensure long durability in the future
- introduce, and provide technical assistance about, the construction procedures associated with Japanese penetration macadam method
- provide improvement measures of, and countermeasures against, soft ground – such as in delta regions.

To effectively achieve these objectives, prior to the trial, a technical workshop was held at the trial site where technical advice could be given to local workers. Later, the results were summarized and input into an improved technical manual on Myanmar's penetration macadam method.

3.2 Site Selection and Construction

A section of pavement in Yegare village, 120 km west of Yangon, was selected for the trial. It is about a 3 to 4 hour drive by car. It is located in a rural, poor agricultural area, which was directly and hardest hit by the 2008 Typhoon Nargise. On the journey from Yangon, gravel roads were uneven and rutted with many potholes. The ground was soft and houses had been flooded prior to the rainy season. The pavements had to be repaired every time they were severely damaged. An example of a road damaged by flooding is shown in Figure 5.

Figure 5: Damaged roadway after flooding

3.2.1 Pavement Structure

The existing gravel road was assigned as the foundation (see Figure 6). For longer durability, a well-sized base material was constructed over the foundation. Finally, and to provide a smooth surface, the Japanese penetration macadam method was adopted as the surface layer (see Figure 7). For road safety, hard shoulder was designed alongside the lanes spaciously enough so that vehicles can pass each other, while earth shoulder was also added for passing of pedestrians.

The lane width was set to be 3.7 m. The transverse gradient was changed to 3% from the initially designed 4%. For the purposes of comparing the durability of the binder, two sections were constructed, one using straight bitumen and the other using emulsified bitumen.

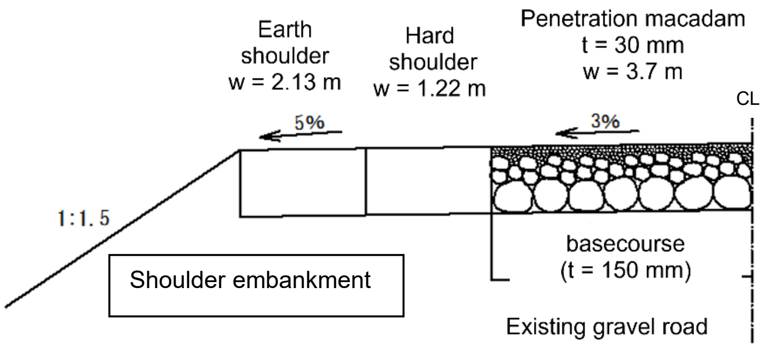


Figure 6: Standard cross section of trial project

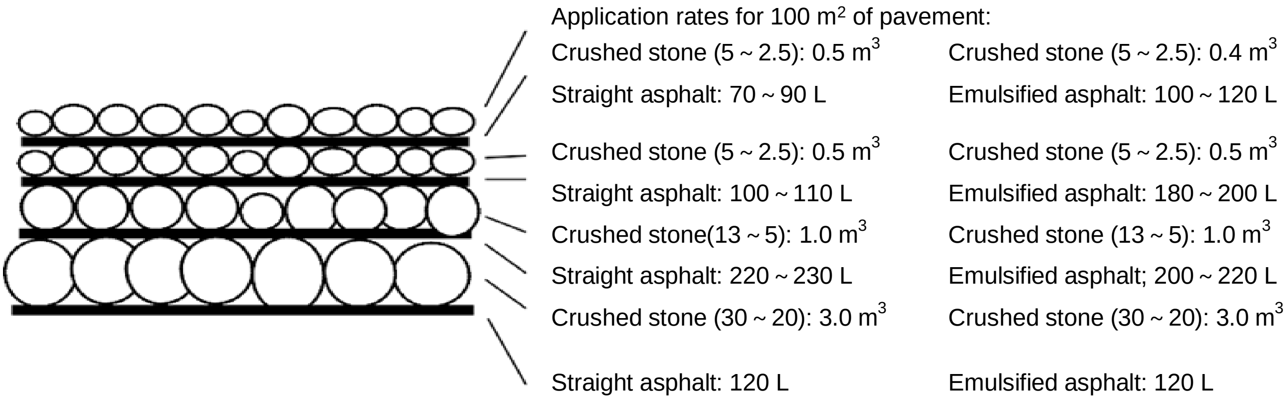


Figure 7: Proposed Japanese macadam specification

3.2.2 Preparation work

For road projects led by Myanmar's Department of Public Works, workers are hired from nearby rural areas. This project was undertaken as a residents' participation-type of construction: they were not only labourers but also trainees given technical advice from Japanese engineers.

Project survey

In Myanmar, a level survey is usually used for the height control of a road project. To make the job easier and more efficient, the traditional Japanese post system using finishing stakes was introduced to trainees through a series of lectures about the procedure of setting-up the post and its application. A photograph of the Japanese post system in use is shown in Figure 8.

Figure 8: Japanese post system

Materials preparation

Desirably, aggregates used in a penetration macadam pavement should be crushed rock with a single fraction size. At the job site, however, aggregate sizes of 13 mm and 5 mm) were manually procured by crushing stones. This resulted in mixed fractions with a lot of dust particles. To obtain a better single fraction, rough sieves, 5 mm and 2.5 mm in size, were made on site and used to screen the original fractions. A photo of the sieves being used on site is shown in Figure 9.

Figure 9: Preparation work (materials preparation)

3.2.3 Construction

Spreading aggregates

Thanks to the popularity of Myanmar's macadam method, workers were accustomed to spreading aggregates. They appropriately spread the crushed stones using an iron bowl. Some workers poured the stones into the bowl, some hauled the bowl to the site, others received it, and a few veterans were in charge of spreading the stones. When a lack of aggregates was observed, the workers were advised to spread some more aggregate to ensure uniformity. Photos of preparing and spreading the aggregates are shown in Figure 10 and Figure 11.

Figure 10: Preparing aggregates

Figure 11: Spreading aggregates

Laying bitumen

Straight asphalt with a penetration grade of 80-100 and an emulsified asphalt were trialled. It was confirmed that spreading could be managed using a hand-made sprayer (see Figure 12). The operation by the veteran workers in charge was smoothly conducted so that technical advice only had to focus on controlling the height of the nozzle and confirming the amount of spreading (see Figure 13).

Figure 12: On-site hand-made sprayer

Figure 13: Laying bitumen

Center joint treatment

The center joint of the treatment is one of the crucial points for achieving a successful penetration macadam pavement. As shown in Figure 14, caution should be taken to ensure that the underlying layers are extended by 50 mm to the neighbouring lane so that construction joints are not vertically successive. If the joints in the subsequent layers are not shifted, as shown in Figure 15, then rainwater will permeate into the deeper underlying layers, leading to early failures such as flushing or stripping of the aggregates. Figure 16 clearly shows 50 mm joint spacing on each layer before moving on to the paving of the other lane.

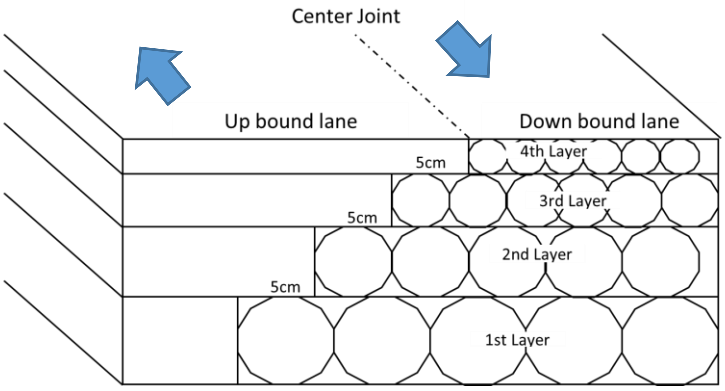


Figure 14: Well planned construction joints

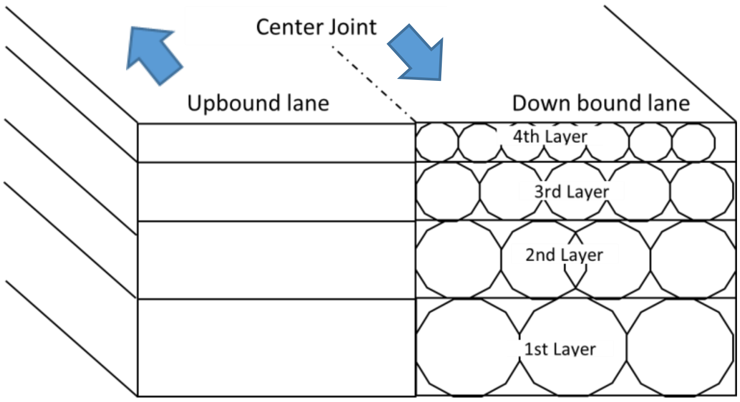


Figure 15: Construction joints to be avoided

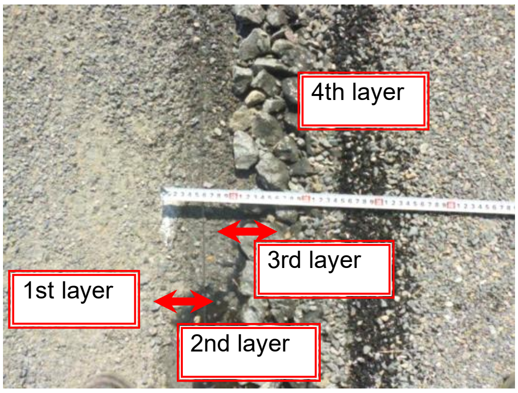


Figure 16: Longitudinal joint

3.3 *Outcome of Trial Project*

The cross-section of the trial pavement was selected to match the penetration macadam pavement used in Japan. In addition to the construction method, advice was given on other technical matters, including planned surveying, the control of materials, the management of road roughness, joint treatment, and other key issues that contribute to pavement durability.

As a result, the macadam road structure was in a good condition and durability was maintained over the four years of visual monitoring (see Figure 17, Figure 18, and Figure 19).

A *Manual on community-inclusive type pavement works for low-traffic-volume roads* was produced during Phase 1 of the project in 2014. Brief details are presented in Appendix A.

Figure 17: Pavement before construction (2014)

Figure 18: Pavement just after construction (2014)

Figure 19: Pavement 4 years after construction (2018)

Before the implementation of the penetration macadam pavement, it took three to four hours to travel by car from Yangon to the region where the trial was conducted. Three years later, the improved road surface greatly reduced travel time to just 60 to 90 minutes. As a side effect, the village started to develop, with an increased number of stores and bus stops emerging along the roadside as shown in Figure 20 and Figure 21.

Figure 20: Activity before project (2014)

Figure 21: Activity three years later

4 PHASE 2 – HOTMIX ASPHALT AND CONCRETE PAVEMENT

4.1 Hotmix Asphalt Pavement

4.1.1 Background

Following the successful technology transfer of the penetration macadam pavement in Phase 1 of the project, trials of high-grade pavements such as hotmix asphalt pavements and concrete pavements were conducted. They will become necessary for the development of national and local roads in the future of Myanmar.

Since there are few asphalt plants in rural areas in Myanmar, and those are owned by private companies, engineers and staffers in the Ministry of Construction (MOC) had little experience in paving with hotmix asphalt, although the MOC intends to install more batch asphalt plants in the future.

For these reasons, the focus of the hotmix asphalt trials was as follows.

- Demonstrate the Japanese empirical design method of pavement design based on local ground conditions and expected traffic loadings.
- Demonstrate the importance of the correct construction of the hotmix asphalt surface layer.
- Make counterparts aware of the importance of quality control of the materials used, and production management at the batch plant.

As in Phase I, technical advice was provided at the trial site. As a result, the MOC agreed to develop an asphalt paving standard for their engineers by compiling a manual based on the findings of the trial.

4.1.2 Technical Assistance

Project survey

The field engineers were not familiar with project surveying using benchmarking and its relationship to the planned height. Therefore, Japanese engineers provided training in the concept and use of benchmarking as shown in Figure 22 and Figure 23.

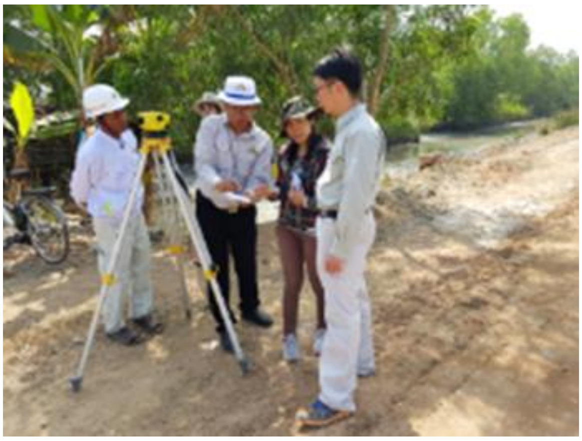


Figure 22: Project survey

Figure 23: Benchmarking

Pre-training seminar

MOC staff were also not used to the methods used for the mix design and quality control of hotmix asphalt. Therefore, prior to visiting the field, a seminar was held at the asphalt plant on key laboratory tests and the construction procedures, including the management of production and the shipment of the hotmix asphalt. Some photos from the seminar are shown in Figure 24, Figure 25, and Figure 26.

Figure 24: Asphalt plant

Figure 25: Seminar

Figure 26: Trial mix at plant

Advice on quality control

In terms of the controlling the gradation of the asphalt mix, the importance of the amount of material passing the 2.36 mm sieve – that divides coarse and fine aggregates – was emphasized. It was shown that the gradation of the aggregates sampled from the hot bin controlled the asphalt mix shipped from the plant. For the same purpose, an asphalt extraction test for measuring asphalt content, and the concept of standard density obtained using the Marshal stability test, were introduced.

In terms of construction, the importance of measuring and controlling the temperature of the hotmix asphalt at the time of its shipping, arrival at the site, placement and compaction was emphasised. Photos of the various stages of the construction of the pavement are shown in Figure 27, Figure 28, and Figure 29.

Figure 27: Paving work

Figure 28: Primary rolling

Figure 29: Secondary rolling

4.1.3 Outcome of trial

The trial construction with hotmix asphalt was completed in January 2018. Fortunately, the asphalt plant used had already been in operation for an Asia Development Bank (ADB) project, so the manufacturing quality was stable. In addition, a certain level of construction quality was ensured by the technical advice provided by the Japanese advisors in cooperation with the Myanmar authorities. The performance of the trial section will be monitored in the future.

In order to popularize the use of asphalt pavements in Myanmar, MOC staff members are expected to be given more opportunities to get involved in, and further understand the design, construction and quality control of, hotmix asphalt materials.

The key issues confirmed through the trial project are as follows.

Preparation work

Until now, project surveys in Myanmar have been limited to certain specified sections. It is recommended that control of the design planned height be applied to the entire section of the road.

Quality control at asphalt plant

Since many plants are owned by the private sector, MOC staff have little experience with the quality control of hotmix asphalt materials. To broaden their proficiency, it is recommended that they become more familiar with mix design and control indices such as density and temperature, through seminars and on-the-job training.

Quality control on site

It is recommended that opportunities be provided for the continuous education of field engineers so they can deepen their understanding of assigned tasks, such as the preparation of formwork, the operation of field plant, and total quality control work in the field. Photographs of the site before and after the project are shown in Figure 30 and Figure 31.

In order to address the above issues, a *Manual on pavement works using hot mix asphalt and ready-mixed concrete* was compiled in Phase 2 of the project in 2018. Brief details are presented in Appendix B.

Figure 30: Site before trial

Figure 31: Site after trial

4.2 Concrete Pavement

4.2.1 Background

In Myanmar, though manually-constructed concrete pavements are seen here and there on urban streets, they are rarely seen on local roads. As with hotmix asphalt pavements, ready-mixed concrete mixing plants are owned by private companies, so the application of concrete pavement varies greatly from region to region. For this reason, the MOC staff's knowledge and expertise differed depending on the area to which they are assigned. A photo of a local mixing plant is shown in Figure 32.

Therefore, as was the case with the hotmix asphalt pavement trial in Phase 2, it was decided to carry out a trial concrete pavement construction and provide technical advice on the construction, leading to the compilation of a paving manual for concrete pavements for MOC staff.

The main aims of the project were to:

- compare two cross-sections – one using Myanmar's design method and the other using the Japanese empirical method
- clarify points to note regarding the constructing of the surface layer using mechanical plant
- demonstrate the importance of material quality control and manufacturing control at the ready-mixed cement concrete plant.

4.2.2 Technical Guidance

Trial mix

The initial mix designed by the Road Research Laboratory of the MOC was found to be difficult in terms of meeting the target slump of 100 mm at the delivery site. The Japanese engineers then demonstrated how to correct the mix so that the slump of the mix arriving at the site would be 100 mm (Figure 33). After that, a small-scale construction test was conducted to confirm the properties (Figure 34). As a result, the mix became more workable, so that the target slump of the mix was increased to 150 mm (maximum 170 mm) leaving the plant and 100 mm at the construction site.

Figure 32: Local mixing plant

Figure 33: Slump test

Figure 34: Small-scale finishing test

Quality control at concrete plant

The materials were manually weighed at the plant, so it was difficult to determine the source of any possible errors every time a sample was weighed. It was recommended that slump testing be conducted on every batch. Furthermore, it was common practice to add water to the mix to adjust the slump on the site. This practice was prohibited (see Figure 35, Figure 36 and Figure 37).

Figure 35: Manual weighing of mix

Figure 36: Manual weighing of mix

Figure 37: Adding water to the mix

Quality control on site

Forms setting

It was recommended that the height of the planned position of the forms be determined using finishing stakes and a strained thread (see Figure 38 and Figure 39). Similarly, another suggestion was made to adjust the forms in case a space was found between them and the underlying surface (see Figure 40).

Figure 38: Setting of the forms

Figure 39: Height adjustment

Figure 40: Space adjustment

Dowel bar

When assembling the chair and installing the dowel bar, it was advised (instructed) that the direction of the bar be parallel to the formwork (see Figure 41, Figure 42 and Figure 43).

Figure 41: Assembling the dowel bars

Figure 42: Installing the dowel bars

Figure 43: Fixing the dowel bars with forms

Spreading with finisher

After the shipped concrete mix was poured into the formwork, a manual finisher and a rod-shaped vibrator was introduced to work the mix (Figure 44 and Figure 45). In addition, the effect of mismatching the finishing speed and the amount of concrete poured into the finisher was demonstrated (see Figure 46).

Figure 44: Manual finishing

Figure 45: Rod-shaped vibrator

Figure 46: Effect of mismatching

Construction joint

Since it took more than 2 hours to make a round trip between the plant and the site, advice was given as to how to deal with the construction joint (see Figure 47 and Figure 48).

Figure 47: Construction joint

Figure 48: Joint part

Curing

Since the curing of concrete pavements was not practiced in Myanmar, the importance of water-curing the pavement was demonstrated (see Figure 49 and Figure 50).

Figure 49: Initial curing

Figure 50: Secondary curing

4.2.3 *Outcome of Trial*

The trial project was completed in January 2018. Despite active cooperation from the Myanmar staff, there a number of errors were committed, and it was necessary to provide basic information to inexperienced field engineers. This was not helped by the fact that a number of tasks had to be conducted in a short period of time. Consequently, sufficient quality could not be attained in the field. For example, although the compressive strength of the on-site curing specimen exceeded the standard value, the construction quality was below the required quality, with some partial cracks propagating near the joints. The long-term performance of each pavement section continues to be monitored and will be evaluated in the future.

A comprehensive *Handbook on pavement works* was compiled by Japanese engineers during the trial. It addresses mix production at the plant, the installation of formwork, field construction, curing, etc. This will be helpful for all users in the future. Brief details are presented in Appendix C.

Figure 51: Pavement before the project

Figure 52: Pavement after the project

5 SUMMARY AND CONCLUSIONS

5.1 Summary

A penetration macadam pavement, built using Japan's knowledge and experience – of which technology was transferred in Phase 1 of the project – is effective as a labor-intensive, community-inclusive construction method because it does not require special equipment, even in cold regions like Mongolia, as already reported by Yano & Onon 2015. It can be confirmed that the Japanese pavement technology, which was once popular and supported the nation's development in the 1960s preceding the high economic growth that followed, has also been successfully implemented even in a tropical region such as Myanmar. This type of pavement is expected to be also effective as an initial infrastructure development technology for underdeveloped countries in the Asian region.

The asphalt pavement and concrete pavement technologies discussed in Phase 2 are also based on the experiences and practices in Japan.

In these high-grade pavements, quality control is important in all stages of the project, from materials preparation, to mix production, and to construction. In addition, the importance of learning basic techniques and continuing education was emphasized. This was accepted by the engineers and field workers, despite the many challenges faced at every stage.

Since most plants are owned by the private sector, raising awareness of quality control by the MOC should lead to an improvement in pavement technology in Myanmar.

The newly-compiled technical manuals on asphalt and concrete pavements should be utilized for human resources development through training, seminars, and various on-the-job approaches in future projects.

5.2 Conclusions

This report describes the conduct and outcomes of a technical cooperation project between the government of Myanmar, the Japan International Cooperation Agency (JICA) and the Japan Road Association (JRA). The project involved two phases, one from June 2012 to September 2014, and the other from April 2016 to December 2019.

Two manuals and a handbook on pavements were produced. In the preparation of the documents, field tests were conducted to address local conditions. The outputs of the project were:

- a *Manual on community-inclusive type pavement works for low-traffic-volume roads*, which was produced during Phase 1 of the project in 2014
- a *Manual on pavement works using hot mix asphalt and ready-mixed concrete*, which was compiled during Phase 2 of the project in 2018
- a *Handbook on pavement works*, which was completed in 2019.

Even under different weather and soil conditions in Myanmar compared to Mongolia, the penetration macadam pavement introduced to Myanmar by Japanese experts was successfully transferred in Phase 1 of the project. As was the case in Mongolia, the transfer of knowledge was made through technical assistance and the compilation of manuals reflecting the local conditions. The technology transfer of high-grade asphalt and concrete pavements in Phase 2 faced various problems such as insufficient experience in basic surveying. The technical manuals that were developed during the project that address these issues will be very useful in terms of successful technical transfer in developing countries in Asia.

6 REFERENCES

Transport and Road Research Laboratory 1970, *Guide to the structural design of pavements for new roads*, road note 29, 3rd edition.

Yano, Y & Onon, R 2015, *incorporating Japanese pavement design practice for a community road in Mongolia*, REAAA Technical report, TC-7, REAAA, Malaysia.

APPENDIX A: MANUAL ON LABOUR-INTENSIVE PAVEMENT WORKS FOR LOW-TRAFFIC-VOLUME ROADS

This manual was developed during the trial construction of the penetration macadam method in the field in order to respond to disaster countermeasures and employment countermeasures. It promotes network construction by manual labour in rural areas, which was the purpose of the Phase 1 of the project.

This manual was based on a Japanese pavement guideline published in 1978, and includes the construction experience and customs in Myanmar. It also includes the management of pavements constructed on weak subgrades in the delta area. It was published in English and the Myanmar language with the aim of spreading its use throughout Myanmar.

The contents of the Manual are as follows:

- Introduction: presents the background and purpose of the manual and the weather conditions in Myanmar.
- Structural design: describes the Japanese empirical structural design method, the effectiveness of which was confirmed in the trials. This made it possible to design the pavement structure according to CBR and traffic conditions. In addition, since the design wheel loads in both countries are different, a conversion formula was included.
- Construction: discusses surfacings, basecourses, earthworks, drainage, and road shoulders.
- Quality control and inspection: stresses the importance of quality control.

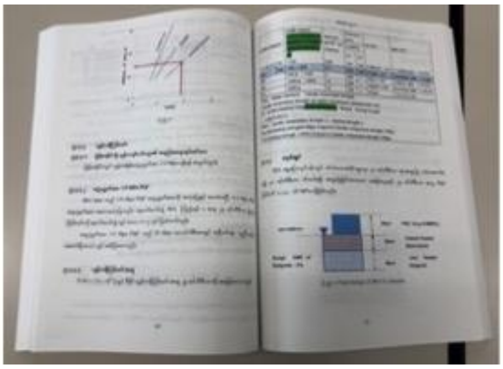
In addition, a trial construction report and structural design examples are included in the Manual.

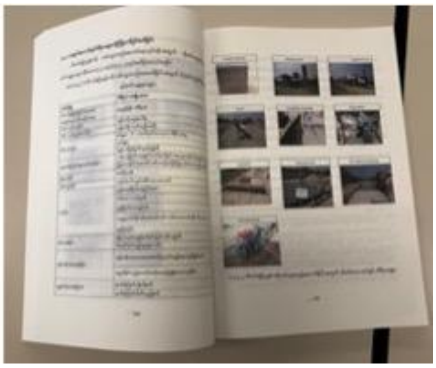
APPENDIX B: MANUAL ON PAVEMENT WORKS USING HOTMIX ASPHALT AND READY-MIXED CONCRETE

This manual was established for the design and construction of hotmix asphalt pavement (national roads) and concrete pavements (state roads/national roads). The technical standards for pavements in Japan and Myanmar are compared and examined, and shortages in Myanmar standards are supplemented with Japanese technology. The section on hotmix asphalt pavements includes a description of batch plants. The Japanese and Myanmar design methods for concrete pavements are compared. In particular, quality control/manufacturing control is emphasized, and points to note regarding material control, quality control methods at ready-mixed concrete and asphalt plants, and pavement construction, are described.

The contents of the Manual are as follows:

- Design and construction of hotmix asphalt pavements: calculation formulas with a reliability of 75% and 90% of the empirical design method in Japan are described. Materials specifications, hotmix asphalt mix design, manufacturing in the batch type plant, transportation, and construction are described.
- Design and construction of cement concrete pavements: the Japanese empirical design method and the Myanmar design method (TRRL 1970) are described together with material regulations, quality control in manufacturing at the plant, local construction methods, and construction management.





APPENDIX C: HANDBOOK ON PAVEMENT WORKS

The two manuals developed in Phase 1 and Phase 2 were for road managers or administrators. In order to further deepen the understanding of site engineers, this handbook was created as a pavement technical manual from the viewpoint of site engineers. This easy-to-understand handbook describes specific construction procedures and management methods at plants and construction sites based on the results of trial constructions. It is hoped that the formulation of this handbook will further spread and disseminate pavement technology in Myanmar.

The contents of the Manual are as follows:

- Preparation work: preliminary survey work for setting temporary benchmarks with differential levelling and marking the planned height, centerline surveying, and indicating the position and height.
- Earthworks (subgrade): the construction of a subgrade (embankment) – mainly focusing on lime stabilization.
- Constructing a subgrade (excavation): detailed information on excavation.
- Basecourse: the construction of cement-stabilized and granular basecourses.
- Surface course work: the construction of penetration macadam pavements, hotmix asphalt pavements, and concrete pavements.