



LAO PEOPLE'S DEMOCRATIC REPUBLIC
PEACE INDEPENDENCE DEMOCRACY UNITY PROSPERITY

MINISTRY OF PUBLIC WORKS AND TRANSPORT (MPWT)

DEPARTMENT OF ROADS

NR 13 NORTH IMPROVEMENT AND MAINTENANCE PROJECT
(SIKEUTH JUNCTION – PHONHONG)

CONCEPTUAL DESIGN

PART I: DESIGN REPORT
(FINAL)

PREPARED BY:



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ABBREVIATIONS

AC	Asphalt Concrete
ADB	Asian Development Bank
ADT	Average Daily Traffic
AIIB	Asian Infrastructure Investment Bank
AP	Affected Person
BOQ	Bill of Quantities
CEMP	Contractors Environmental Monitoring and Management Plan
COI	Corridor of Impact
DBST	Double Bitumen Surface Treatment
DMS	Detailed Measurement Survey
DOR	Department of Roads
DRC	District Resettlement Committee
EA	Executing Agency
EIA	Environmental Impact Assessment
EMA	External Monitoring Agency
EMP	Environmental Management Plan
ESAL	Equivalent Single Axle Load
ESIA	Environmental and Social Impact Assessment
GDP	Gross Domestic Product
GMS	Greater Mekong Sub-region
GOL	Government of Lao Peoples Democratic Republic
HMA	Hot Mix Asphalt
IEE	Initial Environmental Examination
IPDP	Indigenous People Development Plan
Lao PDR	Lao Peoples Democratic Republic
LTEC	Lao Transport Engineering Consultant
m	metre
mm	millimetre
MONRE	Ministry of Natural Resources and Environment
MPWT	Ministry of Public Works and Transport
NR	National Road
NRN	National Road Number
NRSC	National Road Safety Committee
PCC	Portland Cement Concrete
PMU	Project Management Unit
PQ	Prequalification
PRC	Provincial Resettlement Committee
PSA	Poverty and Social Analysis
QA	Quality Assurance
RP	Resettlement Plan
RSAP	Road Safety Action Plan
SBST	Single Bitumen Surface Treatment
SPRSS	Summary Poverty Reduction and Social Strategy
TA	Technical Assistance
TOR	Terms of Reference
US\$	United States Dollar
vpd	Vehicles per day
WIM	Weigh in Motion (axle load measuring system)

EXECUTIVE SUMMARY

Introduction

This Final Conceptual Design Report pertains to the technical and engineering aspects of National Road No. 13 North improvement and maintenance project (Sikeuth – Phonhong) detailed engineering design and procurement phase. The report includes all works carried out after mobilization of the Consultant. This report reflects the data analysis and results. The project covers the length of National Road 13 North (NR 13N), section Sikeuth junction to Phonhong (Vientiane province) 58 km length

Scope of the Project

During 2013, World Bank Group provided a Project Preparation Technical Assistance to carry out a feasibility study of NR13N Vientiane – Phonhong (Vientiane Province) to define the scope of improvements required and to prepare a project suitable for implementation through World Bank Group financing. The scope of work is expected this road section will be improved or constructed in two different sub-sections, sub-section 1 will be improved to an urban road and sub-section 2 will be improved to an ASEAN Highway Class II in level terrain, subject to the approval of DOR.

It is envisaged that the improvement to road standard as described above, road works involve bringing the existing roads to a minimum width as below:

- First part (urban road) width of 23 metres: traffic lanes 3.50x4, bike lanes 1.70x2, sidewalk 1.50x2, and centre median 2 metres
- Second part has designed for two standards, in community area and non-built up area
 - In community area width of 15 metres: carriageway 8 metres, with slow lane 2.50x2, sidewalk 1.50x2
 - In non-built up area width of 12 metres: carriageway 8 metres, with slow lane 2.50x2, shoulders 0.50x2

It will also include pavement strengthening, shoulder and sidewalk improvement, embankment improvement, provision and improvement of drainage structures and bridges. Following the principles established in the project's resettlement framework, effort will be made to restrict all improvement works within the existing right-of-way to minimize land acquisition and resettlement.

Mobilisation of Consultants Team and Equipment

A contract, reference Detailed Engineering Survey and Design for National Road 13 North Improvement and Maintenance Project was signed between the DOR/MPWT and LTEC on 26th July 2017. The effective date for commencement of the contract was 28th July 2017, The Consultant's Team were fully mobilised by 31st July 2017.

The mobilization of the teams and equipments for survey were mobilized to site as below:

- Topographical survey work was started on 1st August 2017
- Sub-soil investigation was started on 8th August 2017;
- Pavement inspection and Benkelman Beam were started on 14th August 2017;
- Bridge inspection were started on the 21st August 2017.

Details of Existing Condition of Road

Pavement conditions on the project roads can be described as follows:

The existing road was paved by DBST carriageway 7 metres width and shoulder width varies 1.00 metre to 1.50 metre, road pavement conditions vary significantly from good to fair with the majority of road sections being rated as low to medium deteriorated. This rating is based primarily of the remaining life of the surfacing and also estimated structural life. The former based on a visual assessment of surface texture and cracking and the latter based on the extent of repairs, present failures and rut depth. At time vehicle speeds average 60 kph

Design Standards

The criteria for the proposed pavement design has been established based on existing data, the project feasibility study, sub-soil investigation and existing pavement inspection undertaken on the project during the data collection period. AASHTO 1993 is applied for the pavement structure design

The standard for the Road and Bridge construction in Lao PDR is based on the Road Design Manual (1996) of the Ministry of Public Work and Transport (MPWT). This manual was developed following technical provisions and standards found in the American Association of State Highway and Transportation Officials (AASHTO) for highways and bridges of the United States. Referred to ToR, ASEAN Highway standard is applied for this project.

Inventory Surveys

A comprehensive inventory of road feature and culvert started on 14th August 2017. The inventory work was completed at the end of August 2017.

The Bridge Engineer completed a detailed inspection of all existing drainage, structures providing sketches and photographic evidence detailing all damage to the substructure, superstructure, surfacing, and approaches. This investigation was started on 21st August 2017 and was completed by the end of August 2017.

Topographical Surveys

Topographical surveys started on 1st August 2017, the scope of the site survey focused on obtaining the existing alignment of the roads, terrain features with all civil works infrastructures, such as culverts, bridges, side drainage and environment along the road alignment. The specific scope of the survey includes the following:

- (i) Survey work on the horizontal alignment, traversing and levelling route
- (ii) Cross-sections and Longitudinal section of existing road
- (iii) Establishment of GPS control points one pair at every 5km, permanent bench marks and reference points one pair at every 2km
- (iv) Topographic mapping along the road alignment 50 m wide covered existing road alignment, at the sharp curve and where it is necessary to improve alignment or widening of road survey area was expanded
- (v) Determination and establishment of locations and dimensional attributes of the culverts and bridges, along with description of their current conditions.
- (vi) Determined and measured flooded level

For more information see Part II Topographical Survey Report, in separated Volume.

Axle Load Analysis

The ESA per vehicle type were calculated from the feasibility study. Legal limit of 11 tonnes for a single axle, dual tyre vehicle to be checked and compared with equivalent factors converted to ESAL. The results were used in the engineering design of the project roads.

Soils and Geological Surveys

For the pavement investigation tests were performed to determine the in - situ sub-base and sub-grade strength, pavement condition, laboratory CBR and properties of the existing road materials.

Sampling of sub-base and sub-grade materials were conducted by hand at test pit at approximately every 1000 metres interval along the alignment.

Field density tests were conducted in the test pits along the alignment of the existing road to determine the in-situ density of the soils encountered;

Dynamic Cone Penetrometer (DCP) tests were performed at approximately 250-metre intervals. Accordingly the California Bearing Ratio (CBR) values were obtained to determine the bearing capacity of the soils;

Laboratory tests were conducted on soil samples from the site. In addition, classification tests and compaction tests were conducted to determine the Moisture-Density relationship (OMC-MDD).

The dimensions of test pits were one square metre, and excavated maximum depth of one metre below the surface to assess the subsurface soil structure. The in-situ density of the soil was determined using the sand cone replacement method (AASHTO T-191). The materials encountered were logged in accordance with unified soil classification system (USCS). The geological profile of the test pits logs were recorded along the DCP profiles every 250 metres. From each test pit, one bulk sample weighing more than 40 kg was transported from the project site to LTEC's laboratory in Vientiane for further testing and analysis. After obtaining the samples, the test pits were backfilled and adequately compacted.

The geological profile of the Test Pit logs are recorded along the DCP profiles and the densities are recorded on the logs will be included in the final geotechnical report, which is currently being prepared. Photo documentations of the field activities, boring data and test pits are also available and formed part of the final geotechnical report documentation.

Geological investigation at bridge locations for support foundation design have done 14 bored holes, with the depth varies from 13 metres to 17 metres used Standard Penetration Test (SPT) method, this is an additional work excluded in the contract for detailed survey and design.

Pavement and Material Surveys

The objective of the soil and material testing is to find suitable sources for construction materials in nearby areas for use in the following:

Fill materials for embankment, subgrades and backfills.

For naturally occurring granular or soil aggregate materials for sub-bases.

For drainage blanket and concreting.

For aggregates for bases course, surface treatment and concreting.

For classifying gravel and sand deposits.

For classifying boulders and rock quarries.

Laboratory Tests

As required for the technical and engineering studies of the project roads, the soil samples obtained from various sites (test pits and borrow pits) in the field were subjected to the following laboratory tests and analysis:

Natural water content test in accordance with AASHTO T265

Sieve analysis tests were conducted in accordance with AASHTO T88-00

Atterberg limit tests were conducted in accordance with AASHTO T89-90

Compaction tests were conducted in accordance with AASHTO T180

California bearing ratio (CBR) tests were conducted in accordance with AASHTO T 193 (4 days soaked, or more if swelling is still observed).

Analysis of Test for Road Construction Materials

The results of the analysis for materials show that out of the 12 borrow pits sites, 8 rivers gravels sites, 9 river sands and 3 quarry sites have been found for possible sources for the project. These soil materials are primarily characterized as clayey sand some gravels, silty gravels, clayey laterites, poorly graded sand and poorly gravel sand, well graded sands and gravel sands, crushed rhyolite.

This shows that the project site should not have a problem for the necessary materials for sub-grade and sub-base construction.

Results of Pavement Investigation

Assessment of the results show that within the top 1.0 metres the CBR values vary from a low of 4% to as high as 67%. Due to variances of CBR in particular test points, there are a total of 76 CBR values recorded. For subgrade layer, according to the road construction manual, the acceptable CBR is higher than 8%. From the set of CBRs obtained, 63 CBRs or 82.89% are higher than CBR 8%. 5 CBRs or 6.58% are CBR 8%. 8 CBRs or 10.53% are less than CBR 8%, which are lower than the prescribed values.

for more information see Part III, Part IV and Part V, in separated volume.

Hydrology and Climate

Vientiane Capital and Vientiane Province are located in a flat zone (called Vientiane Plain). Generally, flows in rivers or streams are varied accordingly to rainy or dry seasons in a year. The rainy season lasts from May to October with the precipitation about from 1350 to 2203 mm/year; the dry season lasts from November to April, humidity about from 46% to 95% per year, and temperature about 15.4°C to 38.3°C per year.

Generally hydrological and hydraulic calculations shall base on analysis of the natural conditions of catchment such as precipitation, geometric condition at the bridge sites with regard to terrain condition in that area.

Since this road project locates in flat zone, land used in this zone is agricultural area mostly is paddy field and other cultivations, in such case the catchment area could not be determined all culverts were installed for balancing water level only.

Hydrological field data collection was carried out in in order to obtain actual data in the project particularly in the area of the bridges, culverts and lower points for the determination of hydraulic and hydrological requirements of them in order to avoid flood problems, field data collection has cooperation with engineers from Department of Public Works and Transport (DPWT) of Vientiane

Capital and Vientiane Province, as well as from the office of PWT of districts who has taken reconnaissance during rainy season especially when flood had happened. The main function of the hydrological and hydraulic data collection is summarized as follows:

- Asked for flooded data and other relevant information recorded by engineer at DPWT and PWT Office of the districts in the project road
- Interview local residents about flooding information
- Measurement of flooded elevation use of levels and elevation was transferred from Bench Mark
- Stream, waterway and outlet or discharged area were inspected by the surveyors and drainage engineer
- Hydrological computations for bridges involve the maximum flood discharge, velocity, water level, backwater effects (afflux) and the scouring tendencies

As results revealed that flooding was happened cause of land used, stream and waterway was filled by land owner, it is not problem of insufficient cross-sectional area of drainage structures

Soil Erosion Problems and Measures

Soil erosion problems have been identified only at abutment of bridges.

Resettlement, Social and Environmental Surveys

These components were conducted by another consultant.

Alignment Standards

The alignment standards are related to design speeds, which in turn are related to the terrain and road types. For Class II road, the design speeds according to the ASEAN Highway standard is 80kph to 100kph for level terrain. This design speed will be adopted for the project road. In some cases the vertical alignment and minimum curve radii will have to be improved for traffic safety and avoided flood

The minimum horizontal and vertical curves are also related to design speed and as specified in Term of Referent (ToR) an ASEAN Highway Standards Class II in level terrain are shown below were adopted

- | | |
|-------------------------------------|-----------------------------|
| - Design Speed (kph): | 80 – 100 |
| - Number of Traffic Lanes: | 2 |
| - Traffic lane width (m): | 3.50 |
| - Min. Horizontal Curve Radius (m): | 200 |
| - Max. Super Elevation (%): | 10 (in rural), 6 (in urban) |
| - Max. Gradient (%): | 6 |

Pavement Type Options

Referred to the ToR, at the preliminary step the pavement design shall prepare two alternatives and submit to DOR-MPWT for decision making before prepare final design, types of pavement to be designed for selection are Asphalt Concrete (AC) pavement and Portland Cement Concrete (PCC) pavement.

The AC pavement will consist of a 300 mm sub-grade (depending on traffic and CBR values of the sub-grade), 200 mm sub-base, 200 mm base course, and subsequently by a 100 mm asphalt concrete. Prime coat will be applied over the base course and tack coat in between the bituminous courses.

The PCC pavement will consist of a 300 mm sub-grade (depending on traffic and CBR values of the sub-grade), 250 mm sub-base, and subsequently by a 250 mm concrete slab.

DOR-MPWT has selected PCC pavement as officially informed to LTEC (the Consultant) by letter Ref. No. 00299/MPWT.DOR, Dated 4th Jan. 2018 for carrying on final design of this project road

Base Course and Sub-Base Design

The parameters and procedure to be used for pavement design are in accordance with AASHTO 1993 method. Data input for the calculation such as axle load and traffic data are in the feasibility report in 2014. This is to accommodate requirement of loaded trucks and commercial vehicles.

When the values of the CBR of the sub-grade are established their effect will be calculated in the pavement design. Currently it is assumed a standard CBR of between 8-14%

Hydrologic Parameters for Hydraulic Design

The design criteria for determining the classification for bridge and box culverts has been done based on the discharge and capacity of culvert, with maximum of 3 cells 3.5x3.5 m(HxW). If greater than this the cross drainage shall be considered as bridge. In accordance with Lao road design standard

As mentioned above, the hydraulic design of drainage structures for roads proceeds by referred to the highest water level as measured from the field. The computations of the structural works will form part of the engineering design of the project, which will be the basis for detailed plans and specifications

Bridge and Box Culvert Design

There are seven bridges in this project consists of five single span bridges, one two spans and one three spans bridges all are segmental pre-stressed concrete I-girder. The Consultant studied reports and the condition of the existing structures and location of those bridges. The following design standards were adopted;

Design Code: AASHTO LFRD
Seismic: zone 2, coefficient A = 0.19
Live load: HS20-44 truck

In the Feasibility Study proposed to reconstruction for all single span bridges. Extension of abutments and piers, and replacement of super structure for two spans and three spans bridges.

As agreed by DOR-MPWT, almost existing bridges are remained at this phase only four bridges are needed to construction particularly on four lanes road section as below:

- Houay Xai Moun Bridge KM 7+019, construction of a new bridge parallel to the existing bridge on left hand side for one traffic direction
- Houay Xon Bridge KM 10+053, reconstruction
- Nam Houm Bridge KM 19+250, construction of a new bridge parallel to the existing bridge on left hand side for one traffic direction
- Nam Phanai Bridge KM 43+716, reconstruction (flooded cause of a dam at downstream)

Type of Structures

The design will be as follows;

- 1) Structures: Pre-stressed Concrete I-Girder
- 2) Bridge Cross-Section
 - a). A new bridge for one traffic direction bridge (one side) the width is proposed at 8 m , comprising of a 7m traffic lane and 1m sidewalk on one side (including kerb and rail)
 - b). A new construction bridge at four lanes road section the width is proposed at 26 m , comprising of a 9 m carriageway, a 4 m gap at centreline (median) and 2 m sidewalk on each side (including kerb and rail)
 - c). A new construction bridge at two lanes road section the width is proposed at 12 m , comprising of a 9 m carriageway and 1.5 m sidewalk on each side (including kerb and rail)

Traffic Safety and Control Devices

A traffic safety was considered on the Project road. Bridges for pedestrian crossing by over pass, road design were used effectively position the various safety guards for the project road and road safety campaign is proposed to perform in the construction stage

The premise of the design is to mitigate those areas that show signs of accident black spots, a full traffic was undertaken to identify where a hazardous curve to be improved, guard rails, sign and signal should be erected.

Project Implementation

The Project will be implemented as an Output Performance Based Road Contract (OPRBC) and the project road has split into two contract packages, Package 1: km 0.00 to km 19.40 (length of 19.40km) and Package 2.: km 19.40 to km 58.00 (length of 38.60km). Procurement will be conducted by DOR-MPWT under the guidelines of World Bank Group. Project coordination will be undertaken by the DOR-MPWT

The construction supervision consultant teams shall be headed by a Team Leader and shall direct the construction supervision. Regular coordination meetings will be held and presided over by the DOR Project Manager.

Data and information sharing between all parties shall be encouraged for the benefit of the entire project and for the interests of the client.

Project construction meetings shall also be regularly set to coincide with accomplishment of major milestones and to be chaired by the Project Manager. During these meetings, accomplishments for each of the components shall be presented along with project wide issues and concerns

Method of Unit Cost Calculation

Cost estimate use of unit rates were issued by DOR-MPWT in 2013, except which item is not available or the rate is unrealistic then the market price was adopted.

Bill of Quantities

The quantities in the Bill of Quantities for the project road have been completed. Refinements has been undertaken on several occasions.

The work quantities for the pavement structure, which include the sub-base, base course, shoulders and sub-grade preparation, is considered uniform for each of the project road for this preliminary cost estimate. The drainage works quantities are also computed using survey results and estimated lineal extents for improvement or reconstruction

Project Cost Estimation

At the first step of the detailed design for the project road, a cost estimate was prepared for two alternatives of pavement types and submitted to DOR-MPWT for selection since October 2017, then the DOR- MPWT issued a letter Ref. No. 00299/MPWT.DOR dated 04 Jan. 2018 to inform LTEC (the Consultant) about confirmed the selection of PCC pavement type

The cost for the project pertains to that of earthworks, pavement structure, drainage, structures, road appurtenances and miscellaneous. Unit costs were used and applied to the entire project road. Information and quantification on earthwork requirements and drainage improvement were already considered and form part of this computation.

The work quantities for the pavement structure, which include the sub-base, base course, shoulders and sub-grade preparation is considered. The drainage works quantities are also computed using survey results and estimated lineal extents for improvement or reconstruction

Summary of construction cost for each alternative pavement type (grand total) was submitted to DOR-MPWT at the preliminary design step:

- | | |
|------------------------------------|---------------|
| 1) Asphalt Concrete (USD): | 77,873,000.00 |
| 2) Portland Cement Concrete (USD): | 93,176,146.40 |

The followings are roughly estimate maintenance cost for each alternative (average):

- 1) Asphalt Concrete (USD): 26,000/km/year = 1,682,000/year
At the first 3 years might not need much maintenances, at the year 15 may be needed overlay
- 2) PCC (USD): 23,232/km/year = 1,347,456/year
At the first 5 years might not need much maintenances, at the year 21 may be needed AC overlay on PCCP

Summary of Construction Cost for Each Contract

After the design and pavement type have been approved by MPWT, cost estimate for each contract has done based on quantity of works can be summarized as the following.

- 1) Contract 1: 4-lane 2-way road, 19.40 km length
 - a. Construction Cost (USD): 47,745,934.81
 - b. Maintenance Cost (USD): 4,521,300.00
- 2) Contract 2: 2-lane 2-way road, 37.377 km length
 - a. Construction Cost (USD): 55,756,391.40
 - b. Maintenance Cost (USD): 4,068,211.00

Conclusion and Recommendation

Conclusion

The following works were taken into the account during conceptual design stage:

- 1) The road pavement structure design will be modified depending on the CBRs of the sub-grade values and traffic volume.

- 2) The alignment mainly follows the existing road alignment, a few places have been improved at hazardous horizontal curves for the purpose of traffic safety in consultation with the DOR and DPWT
- 3) At the portions of flooded is necessary to raise profile has been improved
- 4) The existing drainage system to be rectified and/or re-design to meet the requirement
- 5) The slope protection including inlet & outlet of culverts to be protected by reinforced concrete headwall/wing wall and the grouted rip-rap
- 6) In the village areas a side ditch by rectangular reinforced concrete with covered were designed
- 7) At the community areas a bridge for pedestrian crossing by overpass were designed

The advantages and disadvantages between flexible (AC) pavement and rigid (PCC) pavement are as compared in the Table below were submitted to the DOR-MPWT at the preliminary design step.

Comparison of AC and PCC Pavement Types

Descriptions	AC Pavement	PCC Pavement
Service live	short	long
Sustention	weak	strength
Load acting	concentrated load, stress-strains occurred when wheel load acting on the pavement	distributed load, load transfer to other slabs through dowel bars, concrete slab is reinforced by wire mesh for reaction to strains occurred cause of temperature changes
Initial cost of construction	cheap	expensive
Maintenance cost/live cycle cost	high	low
Weather impact	affected by wet especially flooding	no affected by weather and wet condition
Times for construction	slower than PCC, laying and compacting 2 layers of base-course, blow surface, spraying prime coat and wait for drying at least 2 days	faster than AC, can set form and pour concrete on sub-base layer
Material	import Bitumen	use of local material
Construction of surface course and surface level	Need a good Paver, with skill operator, experienced foremen and technicians to undertake QC at site	only setting form work and check level at connection points properly
Construction Technique to be concentrated	Mixing AC, temperature control, laid and compact problem, weather and pavement shall be dried	mix proportion, dowel bars and tie bars installation to right position and right direction, expansion joint installation, vibration and compaction while pour concrete, concrete curing, joint cutting and joint sealing
Surface texture	Loose skid resistance if poor mix proportion	No problem with skid resistance due to blooming surface/surface texture
Maintenance problem	fast, can be repaired at defect spot only, can open to service when repair work is done	need to cut and remove entire defected slab and wait until concrete strength is met before open to service

Recommendation

The following recommendations were taken into the account in the detailed engineering design during implementation stage:

1) Inspection of existing bridges:

The Contractor shall conduct Bridge Inspection and Bridge Load Rating in accordance with AASHTO LRFR for all existing bridges to be remained

2) Test of existing pavement:

The Contractor shall conduct the following test of existing pavement

- Road surface roughness (IRI)
- Deflection test by Falling Weight Deflectometer (FWD), and evaluate existing pavement structure
- Test pits and sampling on the existing pavement and existing ground on proposed widening area
- Visual inspection and measurement of deteriorated area, and evaluation of deteriorated level in accordance with Method of ASTM-D4695, ASTM-D6433 or as given in ToR provided by the Client

3) Geological investigation at bridge construction site

This work consists of drilling and sampling at abutments by 2 boring holes per abutment or as directed by the Engineer

4) Hydrological study for risk reduction with climate change vulnerability particularly flooding area, and providing hydrological modelling

5) Animal crossing points

As proposed in ESIA Report, if it is agreed by DoR, MPWT the following works shall be performed by the Supervision Consultant and the Contractor

- Joint with local authorities to define animal crossing location as it is appropriately
- Design for construction of dry path facility along the stream and crosses under bridge at abutment on both sides for people and animal movement

1. INTRODUCTION

This Final Conceptual Design Report pertains to the technical and engineering aspects of National Road No. 13 North improvement and maintenance project (Sikeuth – Phonhong) detailed engineering design and procurement phase. The report includes all works carried out after mobilization of the Consultant. This report reflects the data analysis and results. The project covers the length of National Road 13 North (NR 13N), section Sikeuth junction to Phonhong (Vientiane province) 58 km length

Resettlement, environmental and social and gender components were conducted by another consultant.

1.1 Background of the Project

National Road No. 13 North (NR 13N) starts from Vientiane Capital to Northern of Lao PDR (China border). Road alignment through Louangprabang City, Oudomxay Province and ends at Nateuy Junction Louang Namtha Province with a length of 700 km approximately, geographical condition of NR 13N is mainly in mountainous terrain, NR 13N is a part of ASEAN Highway No. AH12. Road section for this project starts at Sikeuth Junction Vientiane Capital and ends at Phonhong Roundabout Intersection in Vientiane Province with a length of 58km (see alignment layout in Appendix 1).

Section of road for this project locates in flat zone (called Vientiane Plain) lays in between Mekong River and Nam Ngum River, the existing road is 2-lane 2-way road, formation width varies 9 metres to 10 metres and DBST surface the latest improvement was done during the beginning of 1990s under the Road 13N Improvement Project (Vientiane to Vang Vieng). The condition of existing road surface is evaluated in the range low to medium deteriorated. Side ditches are mainly filled by soil and vegetation, some of cross drains the stream is also blocked by soil and vegetation. Traffic signs, road marking, guide posts, guard rails are needed to improve for traffic safety

In August 2017, Ministry of Public Works and Transport (MPWT), Department of Roads (DOR) has engaged Lao Transport Engineering Consultant (LTEC) to perform detailed survey and design of this road project. The detailed design phase is based on Feasibility Study Report was done by Lao-Asie Consultants Group in 2014 as stipulated in the ToR accordingly. LTEC had mobilized to the site immediately after signed an agreement for detailed survey and design, duration of field survey and data collection activity was in the rainy season (see photo graph of activities in Appendix 7)

The objective of the Project is to improve access to social services and markets (leading to improved livelihoods and poverty reduction) and enhance the efficiency of the road network and transport in the project area and north part of Lao PDR. It will also improve connectivity to the region and provide improved links between Thailand, China and Lao PDR. The road works will improve both international and northern of Lao PDR connectivity, through the provision of improved ride quality and the construction of bridges and drainage structures. It will involve constructing and replacing inadequate bridges, upgrade and reconstruct badly damaged road sections and lessen the effects of flooding, highways and road safety.

The Government of Lao PDR is implementing the improvements in the Lao PDR sections of the National Road 13 North Improvement and Maintenance Project (Sikeuth - Phonhong) with funding assistance from the World Bank Group and Asian Infrastructure

Investment Bank (AIIB). The Project will be executed by the Ministry of Public Works and Transport (MPWT) through the Department of Roads (DOR) which are responsible for the direct supervision and implementation of the project.

1.2 Report and Support Data

Survey and design report consists of the following parts in separate volumes

- 1) Part I : Design Report (main report)
- 2) Part II : Topographic Survey Report (support data)
- 3) Part III : Report on Pavement Investigations (support data)
- 4) Part IV : Report on Material Sources Investigations (support data)
- 5) Part V : Report on Sub-Soil Investigations (support data)

1.3 Scope of the Project

During 2014, World Bank Group provided a Project Preparation Technical Assistance to carry out a feasibility study of this road section to define the scope of improvements required and to prepare a project suitable for implementation through World Bank Group financing. It is expected that road sections will be improved or constructed to an ASEAN Highway Standard Class II level terrain and Urban Road Standard, subject to the approval of DOR. The scope of work recommended for the road sections in Lao PDR is summarized in following.

- Eliminate hazardous curves
- Raise profile grade level at flooded portions
- Replacement of structurally deficient and narrow bridges (4 bridges)
- Extension of existing culverts and replacing which culvert is not met standard or not enough capacity
- Provision of asphalt concrete/cement concrete road surface
- Provision of traffic control device and road safety improvement

It is envisaged that the improvement to an ASEAN Highway standard class II in level terrain and Urban Road standard, road works involve bringing the existing roads to a minimum width as below:

- First part (urban road) width of 23 metres: traffic lanes 3.50x4, bike lanes 1.70x2, sidewalk 1.50x2, and centre median 2 metres
- Second part has designed for two standards, in community area and non-built up area
 - In community area width of 15 metres: carriageway 8 metres, with slow lane 2.50x2, sidewalk 1.50x2
 - In non-built up area width of 12 metres: carriageway 8 metres, with slow lane 2.50x2, shoulders 0.50x2

It will also include pavement strengthening, shoulder and sidewalk improvement, embankment improvement, provision and improvement of drainage structures and bridges. Following the principles established in the project's resettlement framework, effort will be made to restrict all improvement works within the existing right-of-way to minimize land acquisition and resettlement.

Picture 1 Typical Project Road

Through Paddy Field



Sharp Curve and Poor Visibility



Through Villages



Market Area



1.4 Objectives of the Project

The main objectives of the consulting services are:

- Undertake engineering investigations and topographic surveys;
- Prepare engineering design, quantities and costs estimates for all civil works

1.5 Goals of the Project

The focus of the project is on the long-term goal of providing MPWT and the DPWT with the capacity to manage projects and work programs within their own resources. This is in line with the MPWT's clear ambition to build sustainable road management organizations that can develop, manage and maintain the road assets.

The emphasis of Consultant's support to the DOR and the DPWT is strengthening their capacities and capabilities to manage road improvement components. This will be accomplished by focusing on the following areas:

- Preparation of all documentations required for project approvals by MPWT and World Bank Group
- Detailed engineering design

This focus is well in line with the Consultant's understanding of the current situation

1.6 Mobilisation of Consultants Team and Equipment

A contract, reference Detailed Engineering Survey and Design for National Road 13 North Improvement and Maintenance Project was signed between the DOR/MPWT and LTEC on 26th July 2017. The effective date for commencement of the contract was 28th July 2017. The Consultant's Team were fully mobilised by 31st July 2017.

The mobilization of the teams and equipments for survey were mobilized to site as below:

- Topographical survey work was started on 1st August 2017
- Sub-soil investigation was started on 8th August 2017;
- Pavement inspection and Benkelman Beam were started on 14th August 2017;
- Bridge inspection were started on the 21st August 2017.

2. PROJECT ROAD DESCRIPTION

2.1 The Alignment of Road

The following are the details of the road section in the project and general layout of alignment is shown in Appendix 1.

The road section to be improved is located between Vientiane Capital (Sikeuth Junction) and Vientiane Province (Phonhong Roundabout) an overall distance of 58 Km as shown in Figure 1. This road section completed the improvement during the beginning of 1990s.

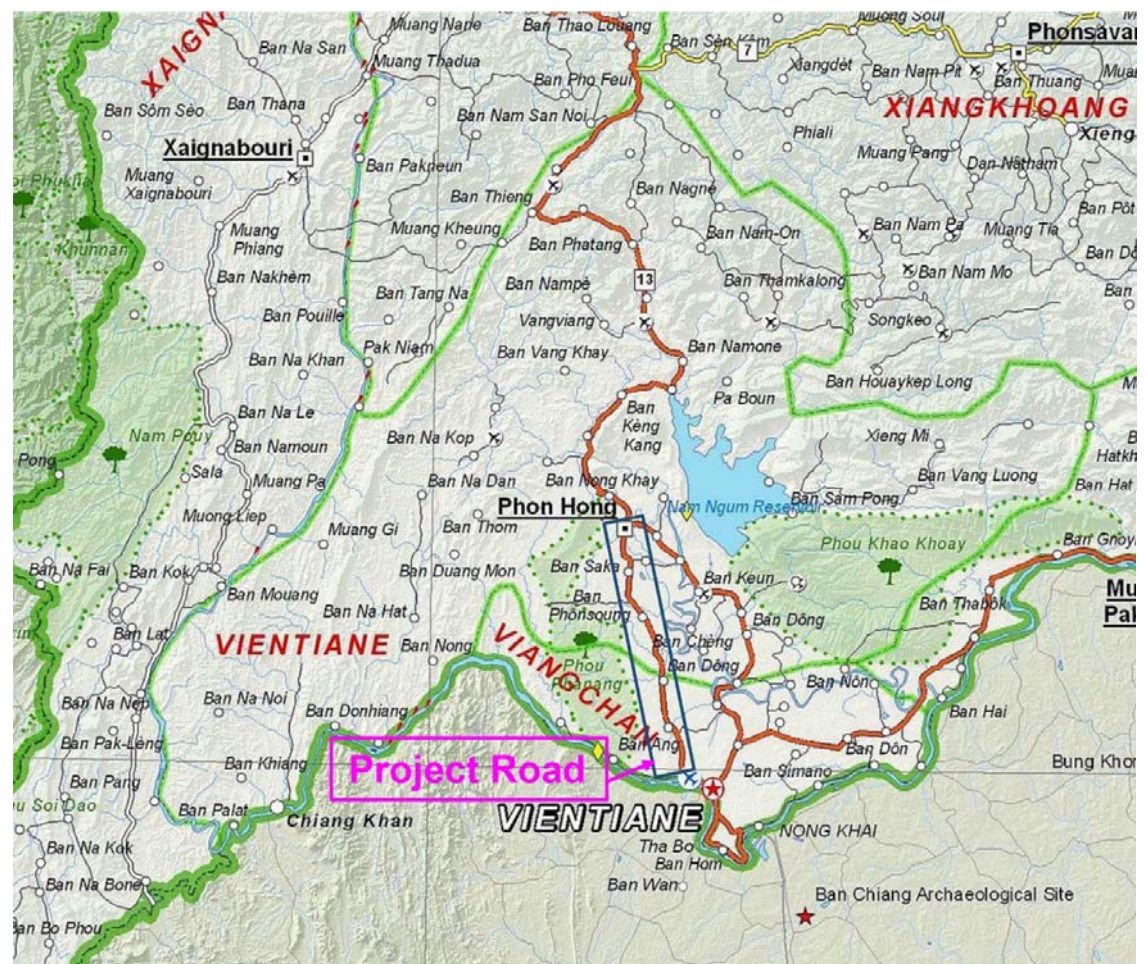


Figure 1: Map of Project Road

The road consists of a 7m carriageway and 1.00 to 1.50m shoulders with DBST surface. The road surface conditions vary significantly from good to fair with the majority of road sections being rated as low to medium deteriorated.

Generally road section in the project has an alignment consisting of straight to gently curved horizontal curves, together with low vertical grades, with the maximum of vertical gradient is 8.3%. The road alignment almost passes through the paddy field and villages. the road follows the flat terrain which means that allowable speeds for light vehicles are reduced in most instances to speeds of 50 kph, but are as low as 40 kph and as high as 80 kph in the non-built up area if the ride quality where acceptable, as the road is often straight. Trucks speeds are, as would be expected 30kph to 60 kph. Proposed improvements include the following:

- (i) Widening of pavement on curves, especially on the hazardous curves to allow vehicles to pass safely.
- (ii) A traffic audit identifying accident black spots and sections needing safety work and signage including markings, guard rails, guide posts
- (iii) Provision of bridge for pedestrian crossing by overpasses at community area
- (iv) Installation of traffic signal at major intersection and pedestrian crossing (zebra), especially school and market area
- (v) Increase turning radii and provision of channelization at main intersections for smooth traffic flows and reduces conflicting points
- (vi) Provision of U-Turn facility in 4-lane section and raised median is provided

2.2 Existing General Features

2.2.1 Existing Road Formation Width

The formation width of the road varies from 9 metres to 10 metres, the road was paved by DBST with earth V-ditch side drain at some parts of the road, V-ditch have dimensions 0.50 depth and 1.0m width. Some part of the road almost of the side ditches are damaged and in need of improvement

2.2.2 Existing Carriageway Width

The carriageway of the road is 7.0 metres width

2.2.3 Existing Shoulders

The shoulder varies from 1.00 metre to 1.50 metre, it is wider in some areas where it passes through village communities it is widened to 1.50 metre. The road pavement edges are badly damaged as the edge of the road is travelled by vehicles.

2.2.4 Details of Existing Geometrics of Road

The road alignment passes through flat terrain, the road width varies from 9.0 metres to 10.0 metres, there are sharp curves with radii less than 150m

2.2.5 Details of Existing Roadside Drainage

Generally, the pipe culverts are installed sufficiently along the road alignment. However, some upgrading and extension of existing culverts improvement of side drains through the road will needed to rectify. The diameter of some of the pipes culverts are smaller than 1.0 metre as required in Lao Road Design Standard

2.2.6 Right of Way

The right of way on National Roads is defined under the Law on Public Roads 021/NA dated 08/11/2016 as 25.0m for the improvement of an existing road. However, the width of this corridor of impact (COI) for the project will vary according to the class of road, width of carriageway and shoulder, drainage, road safety considerations, construction requirements, diversion roads, etc.

2.2.7 Details of Existing Bridges and Culverts

There are seven bridges in this project, all are segmental pre-stressed concrete girder (I-Shape), five bridges are single span, and the rest are two spans and three spans respectively, width of deck is 9m (8m carriageway and 1m foot path). The abutment of existing bridges are simply constructed by cast concrete for pile cap on the ground, there is one bridge at km 43+716 the water level raises beneath the bottom surface of girder cause of a spillway for irrigation has built at downstream of the bridge it is approximately 150m from the bridge centreline, there are four bridges will be constructed. Regarding to the historical water level or high flood level which interviewed from the local people at the site, the current bridge is high enough to avoid the flooding. All bridges cross narrow stream and road project is located in the flat zone and could not be defined catchment area for hydraulic computation. Details of the existing bridges are shown in table below.

Table 1: List of Existing Bridges in the Project

No.	Chainage	Name of Bridge	No. of Spans	Exist. Length (m)	Remarks
1	7+019	Houay Xai Moun	1	18.70	Construction of 1 Bridge Parallel to existing
2	10+053	Houay Xon	1	25	To be replace by new
3	19+250	Nam Houm	1	23	Construction of 1 Bridge Parallel to existing
4	24+862	Nam Xouang	2	49.30	To be remained at this phase
5	43+716	Nam Phanai	1	26.90	To be replaced by new
6	51+331	Houay Thone	1	21	To be remained at this phase
7	54+208	Nam Cheng	3	72.80	To be remained at this phase

1). Current Condition of Bridges

Picture 2: Existing Bridges Condition

Bridge No.01 Houay Xon at Km 10+053



Bridge No.02 Houay Xai Moun at Km 7+019



Bridge No.03 Nam Houm at Km 19+250



Picture 2: Existing Bridges Condition (Cont.)

Bridge No.04 Nam Xouang at Km 24+862



Bridge No.05 Nam Phanai at Km 43+716



Bridge No.06 Houay Thone at Km 51+331



Picture 2: Existing Bridges Condition (Cont.)

Bridge No.07 Nam Cheng at Km 54+208



2) Current Condition of Culverts

Most of the existing culverts were constructed at the same time as the road was constructed during the beginning of 1990s some of them were extended the old culverts were constructed before the last improvement. In general, it is considered that almost of the culverts appear are adequately sized for their catchments as there is no evidence of flood, erosion to the road and damaged to culverts at the outlet end, almost outlet or waterway are blocked earth and vegetation.

The summarized condition of culverts are shows in the table below

Table 2.1 List of the Box Culverts

LOCATION	SIZE (S x H) (m)	No. OF CELL	LENGTH (m)	IN LET/OUT LET STRUCTURES	CONDITION	PROPOSED
2+417	2X1.5	1	32.00	HW+WW	GOOD	EXTEND 16 m
3+610	2X1.5	1	34.00	HW+WW	FAIR	EXTEND 17 m
5+734	4X1.5	1	32.00	HW+WW	FAIR	EXTEND 17 m
7+995	4X2	2	35.00	HW+WW	GOOD	EXTEND 22 m
8+408	4X1	1	33.50	HW+WW	FAIR	EXTEND 18 m
9+816	4X1.5	1	32.50	HW+WW	GOOD	EXTEND 17 m
12+005	2X1.5	2	40.00	HW+WW	GOOD	EXTEND 26 m
13+710	2.5X2	2	35.00	HW+WW	FAIR	EXTEND 18 m
14+328	4X2.7	2	37.50	HW+WW	GOOD	EXTEND 24 m
18+579	1.5X1	1	34.00	HW+WW	GOOD	EXTEND 13 m
18+626	1.5X1.5	1	31.00	HW+WW	GOOD	EXTEND 16 m
20+151	1.5X1.5	2	27.00	HW+WW	GOOD	EXTEND 11 m
27+819	1.5X1	1	32.00	HW+WW	GOOD	EXTEND 7 m
31+406	1.5X1.5	1	32.00	HW+WW	GOOD	EXTEND 7 m
36+409	2.5x2.5	2	24.00	HW+WW	---	NEW BOX CULVERT
55+521	2X1	2	22.00	HW+WW	GOOD	EXTEND 9 m

Table 2.2 List of the Pipe Culverts

LOCATION	SIZE (Dia.)	No. OF CELL	LENGTH (m)	IN LET/OUT LET STRUCTURES	CONDITION	PROPOSED
0+682	1.0 m	1	34.00	HW+WW	FAIR	EXTEND 20 m
0+714	1.0 m	1	35.00	HW+WW	GOOD	EXTEND 17 m
2+000	1.0 m	1	28.00	HW+WW		NEW PIPE
2+835	1.5 m	2	31.00	HW+WW	FAIR	EXTEND 15 m
4+622	1.0 m	1	28.00	HW+WW		NEW PIPE
6+324	1.0 m	2	32.00	HW+WW	GOOD	EXTEND 15 m
6+457	1.0 m	2	28.00	HW+WW		NEW PIPE
6+708	1.0 m	2	32.00	HW+WW	FAIR	EXTEND 13 m
6+847	1.0 m	2	31.00	HW+WW	FAIR	EXTEND 14 m
7+564	1.5 m	2	33.00	HW+WW	FAIR	EXTEND 14 m
7+763	1.0 m	2	31.00	HW+WW		NEW PIPE
8+614	1.0 m	2	32.00	HW+WW		NEW PIPE
8+686	1.0 m	2	31.00	HW+WW		NEW PIPE
8+780	1.0 m	2	44.00	HW+WW		NEW PIPE
9+034	1.0 m	2	30.00	HW+WW		NEW PIPE
9+734	1.0 m	1	33.00	HW+WW	GOOD	EXTEND 16 m
10+208	1.0 m	1	31.00	HW+WW		NEW PIPE
10+445	1.0 m	2	32.00	HW+WW		NEW PIPE
11+130	1.0 m	2	33.00	HW+WW		NEW PIPE
12+799	1.0 m	1	30.00	HW+WW		NEW PIPE
12+846	1.0 m	1	31.00	HW+WW		NEW PIPE
12+953	1.0 m	2	31.00	HW+WW		NEW PIPE
14+027	1.0 m	1	31.00	HW+WW	GOOD	EXTEND 16 m
14+962	1.0 m	1	34.00	HW+WW	GOOD	EXTEND 16 m
15+131	1.0 m	1	31.00	DI+DI		NEW PIPE
15+288	1.0 m	1	34.00	HW+WW	FAIR	EXTEND 15m
16+167	1.5 m	3	37.00	HW+WW	GOOD	EXTEND 17 m
16+581	1.0 m	1	33.00	HW+WW	GOOD	EXTEND 15 m
17+251	1.5 m	3	33.00	HW+WW	GOOD	EXTEND 14 m
17+742	1.0 m	1	28.00	HW+WW		NEW PIPE
17+992	1.0 m	1	30.00	HW+WW	GOOD	EXTEND 11m
18+353	1.0 m	2	30.00	HW+WW	GOOD	EXTEND 13 m
19+026	1.0 m	1	32.00	HW+WW		NEW PIPE
19+528	1.0 m	1	30.00	DI+DI		NEW PIPE

Table 2.2 List of the Pipe Culverts (Cont.)

LOCATION	SIZE	No. OF CELL	LENGTH	IN LET/OUT LET STRUCTURES	CONDITION	PROPOSED
19+768	1.0 m	2	28.00	DI+HW	GOOD	EXTEND 12 m
20+198	1.0 m	2	27.00	HW+WW	GOOD	EXTEND 11 m
20+607	1.0 m	1	21.00	HW+WW		NEW PIPE
20+743	1.0 m	3	26.00	HW+WW	GOOD	EXTEND 11 m
21+070	1.0 m	1	29.00	HW+WW	GOOD	EXTEND 12m
21+242	1.0 m	1	26.00	HW+WW		NEW PIPE
21+611	1.5 m	1	27.00	HW+WW	GOOD	EXTEND 10 m
21+831	1.0 m	1	23.00	HW+WW		NEW PIPE
21+999	1.0 m	2	25.00	HW+WW		NEW PIPE
24+215	1.5 m	3	23.00	HW+WW	GOOD	EXTEND 2 m
25+459	1.0 m	2	31.00	HW+WW	GOOD	EXTEND 9 m
26+244	1.0 m	1	36.00	HW+WW		NEW PIPE
26+626	1.5 m	2	28.00	HW+WW	GOOD	EXTEND 11 m
27+976	1.5 m	2	28.00	HW+WW	FAIR	EXTEND 10 m
29+179	1.5 m	2	28.00	HW+WW	GOOD	EXTEND 9 m
29+549	1.0 m	1	27.00	HW+WW	FAIR	EXTEND 11 m
30+239	1.0 m	1	23.00	HW+WW	GOOD	EXTEND 6 m
30+723	1.0 m	1	23.00	HW+WW		NEW PIPE
31+025	1.5 m	1	24.00	HW+WW	GOOD	EXTEND 5 m
32+050	1.0 m	2	26.00	HW+WW	GOOD	EXTEND 9 m
32+527	1.0 m	1	31.00	HW+WW	GOOD	EXTEND 10 m
32+988	1.0 m	3	24.00	HW+WW	GOOD	EXTEND 8 m
33+342	1.0 m	3	29.00	HW+WW	GOOD	EXTEND 10 m
33+745	1.0 m	1	26.00	HW+WW	GOOD	EXTEND 10 m
34+870	1.0 m	1	24.00	HW+WW	GOOD	EXTEND 8 m
35+019	1.0 m	1	25.00	HW+WW	GOOD	EXTEND 8 m
36+916	1.0 m	1	24.00	HW+WW	GOOD	EXTEND 8 m
37+326	1.0 m	1	23.00	HW+WW		NEW PIPE
37+487	1.0 m	1	27.00	HW+WW		NEW PIPE
38+105	1.0 m	1	24.00	HW+WW		NEW PIPE
38+448	1.0 m	1	26.00	HW+WW		NEW PIPE
38+589	1.0 m	2	32.00	HW+WW	GOOD	EXTEND 14 m
38+923	1.0 m	2	27.00	HW+WW	GOOD	EXTEND 9 m
40+510	1.0 m	1	24.00	HW+WW	GOOD	EXTEND 9 m
41+878	1.0 m	1	32.00	HW+WW	GOOD	REMAINED EXIST. PIPE
42+486	1.0 m	2	26.00	HW+WW	GOOD	EXTEND 8 m
43+426	1.5 m	2	27.00	HW+WW	GOOD	EXTEND 9 m

Table 2.2 List of the Pipe Culverts (Cont.)

LOCATION	SIZE	No. OF CELL	LENGTH	IN LET/OUT LET STRUCTURES	CONDITION	PROPOSED
43+508	1.5 m	1	28.00	HW+WW	GOOD	EXTEND 9 m
44+170	1.0 m	1	26.00	HW+WW		NEW PIPE
44+466	1.0 m	1	27.00	DI+HW		NEW PIPE
45+131	1.5 m	1	27.00	HW+WW	GOOD	EXTEND 7 m
45+241	1.5 m	1	23.00	HW+WW	GOOD	EXTEND 5 m
45+559	1.0 m	1	22.00	HW+WW		NEW PIPE
46+003	1.2 m	2	29.00	HW+WW	FAIR	EXTEND 9 m
46+327	1.0 m	1	22.00	HW+WW		NEW PIPE
46+732	1.5 m	2	32.00	HW+WW	FAIR	EXTEND 13 m
47+259	1.0 m	1	26.00	HW+WW		NEW PIPE
47+386	1.0 m	1	43.00	HW+WW		NEW PIPE
48+527	1.0 m	1	32.00	HW+WW		NEW PIPE
48+934	1.0 m	1	25.00	HW+WW		NEW PIPE
49+341	1.5 m	1	39.00	HW+WW	GOOD	EXTEND 15 m
49+659	1.0 m	1	42.00	HW+WW		NEW PIPE
51+057	1.0 m	1	39.00	HW+WW	GOOD	EXTEND 15 m
51+646	1.0 m	1	25.00	HW+WW	GOOD	EXTEND 5 m
51+812	1.0 m	1	30.00	DI+HW	GOOD	EXTEND 10 m
52+012	1.0 m	1	29.00	HW+WW	GOOD	EXTEND 9 m
52+251	1.0 m	1	28.00	HW+DI	GOOD	EXTEND 10 m
52+359	1.0 m	1	31.00	HW+WW	GOOD	EXTEND 10 m
52+466	1.0 m	1	29.00	HW+WW	GOOD	EXTEND 16 m
52+875	1.0 m	1	26.00	HW+WW	GOOD	EXTEND 6 m
53+361	1.0 m	1	32.00	HW+WW	GOOD	EXTEND 8 m
53+540	1.0 m	1	30.00	HW+WW	GOOD	EXTEND 8 m
53+640	1.0 m	1	33.00	HW+WW		NEW PIPE
54+421	1.5 m	1	37.00	HW+WW	FAIR	EXTEND 9 m
55+613	1.0 m	2	31.00	HW+WW	GOOD	EXTEND 13 m
56+026	1.0 m	1	26.00	HW+WW		NEW PIPE
56+101	1.0 m	1	27.00	HW+WW	GOOD	EXTEND 9 m
56+592	1.0 m	1	25.00	DI+DI		NEW PIPE

Notes:

HW = Head Wall
WW = Wing Wall
DI = Drop Inlet

2.2.8 Details of Existing Climate and Physical Environmental Conditions

1) Physical Environment

The physical environment, on the project roads is tropical and flat terrain. The majority of the alignment traverses flat regions and the road passed through farmland and villages.

The land use of the areas traversed by the project roads is generally agricultural and residential area. Paddy field, animal farm, fruit farm and garden such as vegetable, cucumber, bean, corn, cane, orange and mango are commonly produced in the areas and outside of irrigated paddy areas. The agriculture produce is mainly feeds to market in Vientiane Capital.

2) Meteorology and Hydrology

(1) General Climate Condition

The meteor-hydrological characteristics over Vientiane Capital and Vientiane province are mainly governed by seasonal monsoons.

The rainy season, which is influenced by the south-eastern monsoon, starts in end-April and ends in October. This monsoon picks up moisture from the South China Sea and causes rainfall in the areas.

(2) Rainfall

The mean monthly rainfall of Vientiane Capital is approximately 636.80 mm/month and 780.0 mm/month in Vientiane Province. The rainfall records obtained from Meteorological Department as shown in Appendix 2 indicates that months from end-April to October have high rainfall. The total rainfall of these months counts for about 90 percent of the annual rainfall.

(3) Temperature

The temperature in Vientiane Capital and Vientiane province, as with precipitation, varies with altitude in the flat area and laying along the rivers. The highest temperature occurs in May and June approaching 38.3 °C and the lowest in December and January dropping as low as 15.4 °C.

2.2.9 Suitability of the Project Area for Road Construction

The project road is integral component in the Lao PDR road transport sector and provides connections between the countries (Laos and Thailand) and between provinces.

When upgraded, the road will be contributed to improving the living standards of the population living in the project area and vicinity area, to support policy of the Government of Lao PDR for the poverty alleviation of the population. It will also be facilitated for tourism, there are a lot of tourism places in the project area and vicinity areas such as waterfall, Nam Ngum Reservoir, Nam Ngum Beach, Vangvieng District which is a famous tourism place. The project road links to industrial areas such as Cement factory, hydro powers, etc.

3. METHODOLOGY ADOPTED

3.1 Inventory Surveys

A comprehensive inventory of road feature and culvert started on 16th August 2012. The inventory work was completed at the end of October 2012. The following features were recorded in the field:

- Road width
- Junctions/Inter sections
- Sharp curves
- Pavement condition
- Flood areas
- Side ditches and drainage channel
- Community areas, school locations, market locations, etc.
- Protection
- Embankment
- Bridge condition
- Culvert condition
- Traffic accident
- Traffic signs and traffic control devices

A detailed inspection was undertaken of all existing structures, providing sketches and photographic evidence detailing all damage to the substructure, superstructure, surfacing, and approaches. This investigation was started in mid August 2017 and completed at the end of August 2017.

3.2 Topographical Surveys

For more information see Part II Topographic Report, in separate volume

3.2.1 Methodology

The World Geodetic System 1984 (WGS84) co-ordinate system, as given by the National Geographic Department, were transferred from Based Station points NGD 0001 and GPS K5 at astronomical tower Nongteng Vientiane Capital, then allocated to GPS Control points in the project which established one pair at every 5 kilometres. The method of traverse measurement was done by using the Closed Traverse Method. Permanent bench marks were established on the project roads one pair at every 2 kilometres.

Topographical surveys started on 1st August 2017 and completed at the end of August 2017, the scope of the site survey focused on obtaining the existing alignment of the roads with all civil works infrastructures, such as culverts, bridges and side drainage.

The specific scope of the survey includes the following:

- Survey work on the horizontal and vertical alignments and determination of typical cross-sections;
- Establishment of horizontal control points, bench marks and reference points.
- Determination and establishment of locations and dimensional attributes of the culverts and bridges, along with description of their current conditions.

Topographic survey, including horizontal and vertical alignments and cross-sections, establishment of GPS primary control points, bench marks and reference beacons, has been carried out, as required for the preparation of engineering design to enable construction quantities to be calculated to an accuracy of ± 10 percent.

The basic objective of the topographical survey was to capture the essential ground features along the alignment in order for working out the improvements. The detailed topographical survey was undertaken as early as possible in the work schedule, and based on the Preliminary Engineering Study and adjusted as necessary after reconnaissance surveys.

The topographical surveys is one of the most important and critical field tasks under the services. The detailed topographical survey was undertaken using high precision instruments (total stations and digital data recorders) to expedite the checking of survey data, in a format for use in a sophisticated digital terrain model (DTM). The survey team was having computer and software capability to allow the checking of survey data in the field before it is transferred to the home or design office.

The detailed topographic survey included the following activities:

- (i) Primary control surveys by GPS using GPS base stations. Establishing pairs of GPS primary control benchmarks at every 5km interval;
- (ii) Secondary control traverse surveys starting from a pair of GPS benchmarks and closing in succeeding pairs;
- (iii) Running a continuous closed Traverse along the existing road and realignments, where required, and fixation of all cardinal points such as horizontal intersection points;
- (iv) Collection of details for all features such as structures (bridges, culverts, etc), utilities, existing roads, electric and telephone installations (both O/H and U/G), huts, building, fencing and trees (with girth greater than 0.3 metre), natural features and historical or cultural features falling within the extent of survey.

Criteria for the width of corridor survey is as follows;

- (i) The width of the survey corridor had taken into account the layout of the existing alignment, including the extent of embankment and cut slopes and general road profile. (Note: the existing Right of Way [RoW] is 25m either side of road centreline);
- (ii) In the case where the reconnaissance surveys reveals the need for minor realignments, the traverse lines was run along the identified possible alignment in order to refine the exact design alignment. The width of the survey corridor was increased appropriately to cover sufficient area for detailed design;
- (iii) Where existing roads or tracks intersect the project road alignments, the survey was extended a minimum of 200m along the intersecting roads and 50m along intersecting tracks to allow the improvements to be designed.

The topographical surveys for longitudinal and cross sections have covered the following:

- (i) Longitudinal section levels along final centre-line at every 25m interval, at locations of curve points, small streams, intersections and at the locations of change in elevation;
- (ii) Cross sections at every 25m interval in full extent covering sufficient number of spot levels on existing carriageway and adjacent ground of profile correction course and earthwork calculations. Cross sections have been taken at a closer interval at curves, with maximum interval of 25m. Where curves are continuous and small radius, a “DMT model survey” have been conducted to prevent duplication and overlapping of cross sections.
- (iii) Longitudinal section for intersecting roads for length adequate for design and quantity estimation purposes;
- (iv) For major watercourses (existing or proposed bridges) has included longitudinal section for 200m upstream and downstream from road centre-line and cross section of sufficient width to be 2m above the level of expected high water level;
- (v) For minor watercourses (proposed box culverts or multi-cell large diameter (culverts) sufficient length and width to adequately design inlet and outlet structures and protection measures.

The Consultant has collected details of all important features along the alignment. These features affect the project and should normally include buildings and structures, monuments, burial grounds, cremation grounds, places of worship, stream/river/canal, water mains, sewers, pipes, intersections, trees, plantation, fences, utility services such as electric and telephone lines (O/H and U/G) and poles, etc.

The location of culverts and bridges were also established along the entire Project roads with adequate description as to type, station, dimensions (span length, width, height, etc.), including their physical conditions. The data collection has been collected and analysed. The final documentation includes the engineering drawings consisting of the road plan (1:2,000 scale), typical cross-sections, soils/geotechnical report, and other relevant requirements.

3.2.2 Method of Transverse Measurements

The close traverse and open traverse have been used to measure the traverse measurement, the measurements of this work is used for reference of the transferred coordinates into the baseline.

3.2.3 Profile, Cross Section and Topographical mapping Surveys

Profile and cross-section survey has been done in according to the technical specification of MPWT and LTEC. The survey work includes: (i) type of road comprises of road width, carriageway, shoulder inter-section etc; (ii) survey in details comprises of advertising boards, traffic sign & traffic signal (if any), guardrails, parking lodge, electric poles and other public utilities; and survey in details behind RoW comprises of building, government structure, waterway, fence, large tree, land use, road side etc.

3.2.4 Data Processing

The road design work was carried out using AutoDesk Civil 3D Release 2018 for Windows and AutoCAD, Microsoft excel software package to compute a terrain model and plot the new road alignment and other break-points, drawing preparation. The new alignment was located on the drawings with the help of the cross-sections of the new road

3.3 Traffic Analysis

Data of traffic volume, traffic growth rate, traffic forecast, and axle load are based on feasibility study report

3.3.1 Introduction

During January 2014 the feasibility study consultant conducted classified traffic counts for both NR13N and NR13S, there are three stations were related to this project road, as follows:

- Station 1: Sikeuth Junction (start point of this project)
- Station 2: Naxaithong
- Station 3: Phonhong

From these results the average 24-hour traffic volume were calculated, (see Appendix 3)

3.3.2 Traffic Forecasting Methodology

The feasibility study consultant established traffic growth rates the following assumptions were made and the growth rate is shown in Table below:

- Continuing national economic growth of 7–8% a year on average
- The growth rate in Vientiane Capital and nearest provinces continuing at no less than the national average
- The traffic growth rate continues to outperform the provincial growth rate, due to increased motorisation of transport in the country. Private car, bus use will expand faster than motorcycle use.
- There will be some traffic generated by the road improvement itself, due to the safer road with better riding qualities, as well as the traffic generation from the neighbour countries cross border. This effect is assumed to be greater for passenger transport than for freight.

The forecasting of traffic will be based on the data which was collected from the traffic count, and recent supplementary data. The results shall be used, in part, for the base-course and sub-base design.

Table 4: Traffic Growth Rates of the Road Network in the Project Impact Area

Period	2 Wheelers	Tuk -Tuk	4 Wheelers	Bus	Truck	All Vehicles
1993-1998	-	-	-	-	-	-
1998-2003	-	-	1.7%	-	-	3.7%
2003-2008	7.0%	8.43%	5.8%	-4.1%	8.4%	7.03%
2008-2013	7.3%	11.0%	8.4%	-8.8%	7.3%	8.55%

Source: Feasibility Study of Two Pilot PPP Road Projects in LAO PDR

3.4 Geotechnical and Materials Investigation

Details of Geological investigation and material investigation are shown in separate volume as the following names:

- Part II: Report on Pavement Investigations
- Part IV: Report on Material Sources Investigations
- Part V: Report on Sub-Soil Investigations

3.4.1 Methodology

Necessary investigations have been performed on material found along the road alignment, with samples taken at suitable intervals; particular attention has been paid to sub-surface condition at bridge sites where a new/widened bridge is proposed, through appropriate geotechnical surveys.

- 1) The consultant has made trial pit to ascertain the pavement composition. Test pits have been dug by hand at every 1000m with a size of 1 cubic metre to obtain pavement composition details (pavement courses, material type and thickness). For each test pit, the following information has been recorded:

- Test pit reference (identification number, location)
 - Pavement composition (material type and thickness), and
 - Sub-grade type (textural classification) and condition
- 2) The embankment conditions has been evaluated by visual means and the existence of distress modes (cuts, erosion marks, failure, drops) and extent (none, moderate, frequent and very frequent) of such distress manifestations has been recorded. For sections with severe distress, additional investigations as appropriate have been carried out to determine the cause of such distress. The following details were recorded;
- Embankment
 - General condition
 - Extent of slope erosion
 - Drainage
 - General condition
 - Connectivity of drainage turnouts into the natural topography
 - Condition in cut sections
 - Condition at high embankment
- 3) Based on the data derived from the pavement composition and road and pavement condition surveys, the road section has been divided into segments homogeneous with respect to pavement condition and strength. The delineation of segments homogeneous with respect to strength has been done using the cumulative difference approach (AASHTO, 1993). The frequency adopted are as follows:
- along the existing alignment, DCP test at 250m interval on road edge left and right side alternatively
 - along road alignment, the tests pits have been taken at 1km interval on shoulder for each layer of soil type. A minimum of three samples has been tested corresponding to each homogenous segment. The testing for soil has included:
 - In-situ density and moisture content at each test pit
 - Field CBR using Dynamic Cone Penetrometre (DCP) at each test pit
 - Characterization (grain size and Atterberg limits) at each test pit, and
 - Laboratory moisture-density characteristics (modified AASHTO compaction)
 - Laboratory CBR (4 Day soak and swell), longer if swelling continued.

3.4.2 Geotechnical investigations and sub-soil exploration

The Consultant carried out geotechnical investigations and sub-soil explorations for the proposed bridges, bridge extensions as necessary for proper design of the works and conducted all relevant laboratory and field tests on soil and rock samples.

3.4.3 Material Investigation

The Consultant has investigated the suitability of locally available materials and, where necessary, locate quarries, river sand and gravel, borrow pits and assessed the quality and quantity of material and hauling distance;

- 1) The Consultant has undertaken field and laboratory testing of the materials to determine their suitability for various components of the work.
- 2) It was ensured that no material shall be used from the RoW (25m either side of road centreline) except by way of levelling the ground as required or for landscaping and

planting of trees or from cutting of existing ground for obtaining the required formation levels.

- 3) Environmental restrictions, if any, and feasibility of availability of sites for the civil works contractor(s) has been duly taken into account while selecting new material source locations.

The Consultant has tested soil samples by classification (for example: Atterberg limits, CBR and suitability for soil stabilization); undisturbed samples shall be selected for the determination of the main mechanical characteristic and construction materials for grain-size distribution and plasticity characteristics, unit weight and water absorption, Los Angeles abrasion, bitumen adhesion and petro graphical and chemical water analysis.

3.4.4 Laboratory Testing

As required for the technical and engineering studies of the project roads, the soil samples obtained from various sites (test pits and borrow pits) in the field were subjected to the following laboratory tests and analysis:

- Natural water content test in accordance with AASHTO T265
- Sieve analysis tests were conducted in accordance with AASHTO T88-00
- Atterberg limit tests were conducted in accordance with AASHTO T89-90
- Compaction tests were conducted in accordance with AASHTO T180
- California bearing ratio (CBR) tests were conducted in accordance with AASHTO T 193 (4 days soaked or more if swelling was observed).

For the samples obtained from rivers, the tests conducted were as follows:

- Sieve analysis tests of fine and coarse aggregate AASHTO T27-88
- Fineness modulus (FM)
- Organic impurity AASHTO T21-00
- Los Angeles Abrasion test AASHTO T96-99
- Unit weight AASHTO T19
- Specific gravity AASHTO T85-91 (1996)
- Soundness of aggregate AASHTO T140
- Coating and stripping AASHTO T182-84 (1998)
- The samples obtained from the quarry sites were subjected to the following tests:
- Sieve analysis tests of fine and coarse aggregate AASHTO T27-99
- Los Angeles Abrasion test AASHTO T96
- Specific gravity AASHTO T85-91 (1996)
- Coating and Stripping AASHTO T182-84 (1998)
- Fineness modulus (FM)
- Soundness of aggregate AASHTO T140

For the pavement investigation, the following tests were performed to determine the in-situ sub-base and sub-grade strength, pavement condition, laboratory CBR and properties of the existing road materials. The methodologies were as follows:

- Sampling of existing sub-base and sub-grade materials and existing ground were taken from test pits dug by hand with a size of 1 cubic metre at approximately 1000 metre intervals along the alignment on existing road and existing ground alternatively.
- Field density tests were conducted in the test pits along the alignment of existing road to determine the in-situ density of the soil encountered.

- Dynamic Cone Penetrometer (DCP) tests were performed at approximately 250 metre intervals on existing road and existing ground alternatively. California Bearing Ratio (CBR) values were obtained to determine the bearing capacity of soils accordingly.
- Laboratory tests were performed on soil samples from the site. In addition, soil classification tests and compaction tests were conducted to determine the moisture density relationship (OMC-MDD) accordingly.

For more information please see summary test results in Appendix 9, and separate report as mentioned in Section 3.4

3.4.5 Hydraulic and Hydrological Investigations

The bridge engineer completed a detailed inspection of all existing bridges providing sketches and photographic evidence detailing all damage to the substructure, superstructure, surfacing, and approaches. This investigation was undertaken during August 2017 was in rainy season.

The existing hydrological regime was studied in detail, based on rainfall and flood records, supplemented by detailed field investigations, the hydraulic and hydrological investigation has been carried out to assess existing cross-drainage capacity and propose additional drainage structures, and improvement of existing by replacement of new structures or extensions to existing structures where these are otherwise structurally sound, as well as to establish the adequacy of road embankment levels.

These investigations have been carried out for all existing drainage structures along the road. The Consultant has made a desk study of available data on topography (topographic maps, stereoscopic aerial photographs, and satellite imagery), storm duration, rainfall statistics, top soil conditions, vegetation cover, etc. so as to assess the catchments areas and hydraulic parameters for all existing and proposed drainage provisions. The findings of the desktop study were concluded that is difficulty to determine the catchment area due to the project road lays in flat zone, most culverts installed for balancing water level. According to data obtained from the field investigation revealed that flooding happened cause of land used changed, outlet, waterway and drainage channel were filled by soil to block water course.

The Consultant has collected information on high water levels (HWL), low water level (LWL), etc. from DPWT and PWT offices recorded, local inquires and visible signs, if any, on the structure components and embankments. Local inquires had also been made with regard to the road sections getting overtopped during heavy rains (see Table 3 Flooded Locations).

The Consultant has made an inventory of all the structures (bridges, culverts, etc.) along the road as well as a condition and structural assessment survey. This survey was carried out by senior experts of the Design Consultants and presented in a tabular form covering relevant physical and hydraulic parameters.

The dimension and shape of the existing culverts were recorded at each site, as it necessary whenever the extension of culverts and replacing with new one is required.

Vientiane Capital and Vientiane Province is located in a flat zone and closed to river height different of terrain is small, in this case it is difficult to define watershed/catchment area. Generally, flows on the ground surface or in streams are steadily according to flat terrain.

Hydrological field reconnaissance was carried out in order to obtain actual data in the area of the existing bridges and existing culverts for the determination of hydraulic and hydrological requirements, in order to avoid flooding problems.

Table 3: Flooded Locations

No.	Chainage	Detailed Design Measured		FS Measured ^{*)}	
		Flooded Level	Depth (m)	Flooded Level ^{*)}	Depth (m)
1	7+350 – 8+425	172.286	0.50		0.50
2	8+425 – 9+000	172.288	0.50		
3	9+475 – 10+000	173.460	0.40		0.50
4	10+130 – 10+275	173.473	0.20		0.20
5	12+400 – 12+975	173.283	0.30		
6	24+100 – 24+550	170.984	0.50		
7	25+135 – 25+215	170.504	0.30		
8	25+400 – 25+575	171.819	0.30		
9	31+810 – 32+400	170.625	0.30		
10	33+400 – 34+240	172.723	0.30		
11	38+450 – 38+850	177.594	0.25		
12	43+400 – 43+625	178.974	0.50		
13	43+800 – 43+925	178.974	0.40		
14	45+950 – 46+100	177.353	0.28		0.30

**) Level of FS survey could not be compared due to survey monuments were not found*

4. DESIGN STANDARDS

4.1 Introduction

The criteria for the proposed pavement design has been defined by the DOR-MPWT, the project feasibility study. As required by DOR-MPWT at initial step of the design the consultant shall be prepared two alternatives of pavement types Asphalt Concrete (AC) and Portland Cement Concrete (PCC), prepared cost estimate for comparison then submit to DOR-MPWT for decision before the consultant continue to prepare the final design. AASHTO 1993 is applied for the pavement structure design.

4.2 Current Road Design Standards

The standard for this project road and Bridge construction in Lao PDR is based on the Road Design Manual (1996) of the Ministry of Public Work and Transport (MPWT). This manual was developed following technical provisions and standards found in the American Association of State Highway and Transportation Officials (AASHTO) for highways and bridges of the United States. As required in ToR, ASEAN Highway standard is applied for this project.

4.3 Road Standards Adopted for the Project

According ToR as required by the DOR-MPWT, ASEAN Highway Standard Class II in level terrain is applied for this project. However, as specified in ToR and actual location of road, the urban road standard with divided 4-lane 2-way road will be applied at the first section or as called four lane section at the first 20 km.

4.4 Road Standard Application

- 1) The following design standards, shown in table 5, have been adopted for the project roads.

Table 5 ASEAN Highway Standards

Highway Classification	Primary (4 or more lanes) (control access)			Class I (4 or more lanes)			Class II (2 lanes)			Class III (2 lanes)			
	L	R	M	L	R	M	L	R	M	L	R	M	
Terrain classification													
Design speed (km/h)	100-120	80-100	60-80	80-110	60-80	50-70	80-100	60-80	40-60	60-80	50-70	40-60	
Width (m)	Right of way			(50-70) ((40-60))			(40-60) ((30-40))			30-40			
	Lane			3.75			3.50			3.00 [3.25]			
	Shoulder			3.0		2.5	3.0		2.5	2.5		2.0	1.5 [2.0]
Min. horizontal curve radius (m)	390	230	120	220	120	80	200	110	50	110	75	50	
Type of pavement	Asphalt/cement concrete			Asphalt/cement concrete			Asphalt/cement concrete			Double bituminous treatment			
Max. super elevation (%)	(7) ((6))			(8) ((6))			(10) ((6))			(10) ((6))			
Max. vertical grade (%)	4	5	6	5	6	7	6	7	8	6	7	8	
Min. vertical clearance (m)	4.50 [5.00]			4.50 [5.00]			4.50			4.50			
Structure loading (minimum)	HS20-44			HS20-44			HS20-44			HS20-44			

Note:

1. Abbreviation: L= Level Terrain, M = Mountainous Terrain, R = Rolling Terrain
2. () = Rural, (()) = Urban
3. [] = Desirable Values
4. The right of way width, lane width, shoulder width and max. super-elevation rate in urban or metropolitan area can be varied if necessary to conform with the member countries design standards.

Source : www.aseansec.org/ahnp_b.htm

- 4) Minimum horizontal radius and super-elevation can be determined from this equation

$$e + f = \frac{V^2}{127R}$$

Where:

- e = super elevation (m/m)
- f = side friction factor, f = 0.10
- V = design speed (km/h)
- R = horizontal radius (m)

Typical cross sections of roads are shown in Appendix 4

4.5 Terrain Classification

The simple classification of “flat”, “rolling” and “mountainous” has been adopted (from “Overseas Road Note 6, A guide to Geometric Design” published by the Transport Research Laboratory, UK) and is defined by both subjective description and by the average ground slope. The average ground slope is measured as the number of 5 metre contour lines crossed per kilometre on a straight line linking the two ends of the road section (the slope may be interpolated using other contour intervals on a proportional basis).

The specific terrain classifications are as follows:

- 1) Flat (F) : 0 – 10 five metre ground contours per kilometre (level or gently rolling terrain with largely unrestricted horizontal and vertical alignment. The road will, for the most part, follow the ground contours and the amounts of cut and fill will be small).
- 2) Rolling (R): 11 – 25 five metre ground contours per kilometre (rolling terrain with low hills introducing moderate levels of rise and fall with some restrictions on vertical alignment.
- 3) Mountainous (M): greater than 25 five metre ground contours per kilometre (rugged, hilly and mountainous with substantial restrictions in both horizontal and vertical alignment. As the terrain becomes more difficult, larger amounts of cut and fill will generally be required.)

4.6 Formation

The road formation cross section and other key design parameters shall comply with the following guidelines:

Embankments Slopes 1V:2H

1V:3H desirable for embankments up to 1.0m height

1V: 1.1.5H for embankments greater than 4.0m height

Cut Slopes 1V:0.5H with benches 1.5m wide at each 5.0m height of cut (in rock slopes may be steepened to 1V: 0.25 H)

Adverse cross fall; adverse cross fall should be eliminated on curves less than:

flat terrain : 1,500m minimum radius

rolling terrain : 1,000m minimum radius

mountainous terrain: 500m minimum radius

curve widening: In accordance with AASHTO Design Standards

4.7 Bridges

In general, the design basis for existing and new bridges is as follows:

- 1) New bridges should have varies from 8.0m to 18m wide decks excluding footpaths and median on precast piled or spread footing foundations. The design live load standard for new bridges is HS 25–44.
- 2) Existing bridges could not be widened due to existing substructures were simply constructed and more than 25 years old. Existing bridges are 7.0m wide decks excluding footpaths these bridges shall be visually assessed for possible need for other remedial work on the structure to meet the necessary design life. Bridges that are noticed to need additional loading test shall be done during construction phase.

- 3) Minimum footpaths 1.0m wide on one side of the structure are required for all bridges.

Typical cross sections of bridges are shown in Appendix 5

4.8 Pavement

Portland Cement Concrete Pavement is selected for this project road, the pavement design is to be based on a 20 years design life. The basic pavement structure shall be as follows:

- Surface course concrete slab 250mm
- Sand cushion 100mm
- Granular Sub-Base: CBR > 35% @ 95% MDD (equivalent standard for regraded/ rerolled material or scarified/ rerolled material), 200mm thickness
- Sub-grade (upper 300mm of embankment or cut) : CBR > 8% @ 95% MDD
- Primed shoulders

4.9 Right of Way

The Right of Way for National Roads is defined under the Road Law 021/NA dated 08/11/2016 as 25.0m either side of the road centreline for the improvement of the existing road (this is land available under the Land Law 04/NA dated 21/10/03 as Communication Land under the MPWT for road works). In order to avoid unnecessary resettlement, as well as, to restrict adverse environmental impacts through excessive “clearing and grubbing” by contractors, the MPWT defines an impact corridor for each project, the width of this corridor varies according of class of road, width of carriageway and shoulders, drainage, road safety considerations, construction requirements, diversion roads, etc.

5. ENGINEERING SURVEYS AND DESIGNS

5.1 Traffic and Axle Load Analysis

5.1.1 Feasibility Study Review

The Feasibility Study (FS) was completed in 2014 for Two Pilot PPP Road Project in Lao PDR selected NR13S Vientiane to Paksan and NR13N Vientiane to Vangvieng. This project road is a part of National Road No. 13 and a part of ASEAN Highway No.AH12, the project road length is 58 km. According to the contract for detailed design Consultant, some of data shall be used data from FS in order to minimize time for data collection especially topographic, geology and material, traffic and design also update existing design data. But the reality topographic data could not be used due to Bench Marks/Referent Points not available in the site, coordinate (N,E) was not used in previous survey and elevation was not given by National Geographic Department of Laos, geologic data is not clear and not enough information, design data is not met the requirement and referent data was not available. As described, detailed design consult needed to undertake full detail survey, only traffic data has used data from FS report.

- 1) Traffic Data

Traffic volumes have used from FS report was done traffic count in January 2014 as shown in Table below.

Table 6: Traffic Count Data

Annual Average Daily Traffic (AADT) at 13N Road

No	Vehicle Type	AADT Traffic Volume in 13 N Road (Year 2014)		
		Section 1	Section 2	Section 3
1	Motorcycle	12,443	5,993	5,517
2	Tuk-tuk	236	109	28
3	Car, Jeep, & Pick-up	7,116	3,406	2,553
4	Van	1,733	1,038	825
5	Small Bus	525	343	279
6	Medium and Heavy Bus	182	136	140
7	Light Truck	2,228	1,571	1,038
8	Medium Truck (Two Axle)	661	432	297
9	Heavy Truck (3 & 4 Axles)	665	305	368
10	Heavy Truck (5 Axle & more)	151	118	59
11	Hand Tractors	31	58	57
12	Bicycles	204	220	292
	Total	25,971	13,509	11,161

Source: Feasibility Study of Two Pilot PPP Road Projects in LAO PDR

2) Traffic Analysis

The forecasts for 2040 are as summarized in FS Report Chapter 7 Annex 7.1, but in the pavement design needs 20 years analysis period up to Year 2038. The table shows the traffic volumes as the total number of each type of vehicles, see Appendix 3 forecast traffic volume at the survey locations

3) Axle load data

Axle load data used the result of the investigation as given in FS Report and as shown in Table below, and the result of axle loads survey from the other project roads in Lao PDR is summarized in Table 7 below. The “Regulation of Allowable Gross Weight for Transport vehicles” dated the 5 March 2002 specifies the following maximum axle load weight for different axle and wheel groups:

- Single Axle(2 wheel): 2.9 tons
- Single Axle: 9.1 tons
- Tandem Axles: 16.4 tons
- Triple Axles: 19 tons

Table 7: Axle Load Data

Srl No	Vehicle Types	13N Road			13S Road		
		Number of Vehicles Surveyed	Load / Vehicle (kg)	Load / Axle (kg)	Number of Vehicles Surveyed	Load / Vehicle (kg)	Load per Axle (kg)
1	Small Bus	18	4,258	2,129	32	4,674	2,337
2	Large Bus	11	14,917	7,458	28	14,110	7,055
3	Light Truck	51	4,926	2,463	37	4,442	2,221
4	Medium Truck	77	10,960	5,480	59	9,890	4,945
5	Heavy truck (3 & 4 axles)	106	29,631	9,877	97	36,791	12,264
6	Multi-Axle Truck (5 & more axles)	13	66,520	13,304	65	50,590	10,118

Source: Feasibility Study of Two Pilot PPP Road Projects in LAO PDR

5.1.2 Road Pavement Design

1) Design Method

The pavement design has been completed based on existing data, observations, surveys and investigations. In this Technical Design Report some considerations concerning the pavement design have been made to parts of AASHTO, Guide for Design of Pavement Structures 1993.

The above literature describes and provides specific methods and procedures, which can be used for study and evaluation and recommendations of pavement design, alternate design of rehabilitation, overlay and other methods of design and construction. In addition to the factors mentioned in the above literature there are a number of factors which are left to the designer for final determination, e.g. drainage conditions, capillary actions, environmental factors and terminal serviceability of the pavement. Data, parameters, factors input in the pavement structure analysis are as described in the following

Forecast design Equivalent Single Axle Load (ESAL) formula

$$w = \sum ESA \left[\frac{(1+g)^t - 1}{g} \right] \times 365 = W_{18}$$

Where:

t : is analysis period (year), this project has adopted 20 years

g : is growth rate (%), this project has adopted 8.55%

Traffic distribution on the traffic lane is given by;

$$W_{18} = D_d \times D_L \times w'_{18}$$

Where:

D_d : Traffic direction, this project is 2 directions : $D_d = \frac{w'_{18}}{2}$

D_L : Traffic distribution on a lane (%), this project is assumed 80% of D_d

Traffic volume in the year 2018 as forecasted in FS report is 7,316 ADT. Vehicle types to be taken into the account are pickup up to heavy trucks, which type has weight lower than pickup are omitted.

Table 8: Input Data for Pavement Design

No.	Description	Values
1	Rigid Pavement Type	JRCP
2	Selected Slab Thickness, D (mm)	250
3	Terminal Serviceability (Pt)	2.5
4	Initial Serviceability (Po)	4.5
5	Reliability Level, R (%)	90
6	Overall Standard Deviation, So	0.33
7	Design ESA	9.665×10^6
8	ESA distributed per lane	4×10^6
9	Concrete Strength (MPa)	30
10	Sub-Based Material (CBR)	35
11	Sub-Grade Material (CBR)	8
12	Drainage Coefficient (Cd)	1
13	Slab Length (m)	10
14	Slab Width (m)	3.5

Reinforcement can be determined from this equation

$$A_s = \frac{WfL}{2f_s}$$

Where:

A_s = cross-sectional area of reinforcing steel (cm^2/m of concrete slab)

W = weight of concrete slab (kg/m^2)

f = friction factor (about 1.50)

L = length of concrete slab (m)

f_s = allowable steel stress (kg/cm^2)

The results of pavement structure calculation is shown below

- Concrete Slab by Concrete C30 = 250mm
- Sand Cushion = 100mm
- Aggregate Sub-Base, CBR: 35 = 250mm
- Selected Sub-Grade, CBR:8 = 300mm

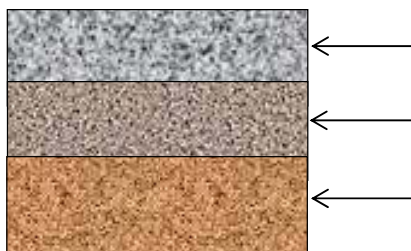


Figure 2: Pavement Structure

2). Sub-Base Course

The sub-base course layer is an important load spreading layer in the pavement structure. It enables stresses from traffic loads to be reduced to acceptable levels as designed in the sub-grade, and acts as a separation layer between sub-grade and base course. The upper layer of the sub-base course also acts as a working platform for the construction of the upper pavement layers, supporting construction traffic and base course paving equipment. The selection of the sub-base course material will therefore depend on the design function of the layer and the anticipated moisture regime, both during construction and in service. The materials for sub-base course are usually obtained from borrow-pits. Thorough investigations of borrow pits and its materials are therefore required to establish that the materials in the proposed borrow pits are meeting specification requirements. As the properties of the materials in a borrow pit may vary within short distances horizontally and vertically it is very essential that excavation and stock piling be properly done, frequently tested and controlled.

The minimum CBR for subbase materials, at the highest anticipated field moisture content, should be 35% when compacted to 95% of the density obtained in the equivalent AASHTO Compaction Test T180, Method D.

(i) Bearing Capacity

The properties of the borrow pit material should be determined by particle size analysis (ASSHTO T 88) Atterberg Limits (ASSHTO T 89 and T 90) and Modified Proctor (AASHTO T 190, Method D). The strength of the sub-base course material should be determined when the sub-base is compacted in conformity with CBR tests (AASHTO T 193) to the highest anticipated moisture content at the compaction to the specified field density. In order to achieve the required bearing capacity and for uniform support to be provided to the upper part of the pavement structure particle size distribution and plasticity properties (Atterberg Limits) should be performed during construction as well, in addition to the field density and Modified Proctor tests. When in doubt of material not meeting specification requirements. CBR tests should be carried out on material from the layer placed on the road.

(ii) Use During Construction

In addition to the requirements governed by the pavement structure design the sub-base might also have to meet requirements by its ability to support the contractor's construction traffic without excessive deformations and rutting and ravelling. The sub-base shall also protect the sub-grade during wet seasons. Specified particle size and plasticity criteria are given in the Specifications. However, it might be desirable for the Contractor to use a reasonably homogenous material which possesses properties similar to those of a good surfacing material for unpaved roads. The material should be well graded and have a plasticity index at the lower end of the appropriate range for an unpaved road wearing course.

5.1.3 Design and Construction Method of Approach

The following method of approach will apply;

- (i) For the purposes of design, the sub-grade strength CBR range was derived from in-situ dynamic cone and laboratory CBR testing of both in-situ and potential borrow materials, and the overall pavement layer thicknesses determined accordingly. The details of the extents and construction thicknesses for surface treatment pavement sections are given below.
- (ii) The Contractor shall undertake in-situ CBR or dynamic cone testing of the existing ground in all lengths where the Engineer considers that such data is of relevance to the pavement design, i.e. where the existing ground, after any required clearing and grubbing, has to be excavated to provide for the pavement construction or where the existing ground level lies within 1.00 metre below proposed formation level in fill. In the former situation the CBR values of the existing ground shall be those relevant to the zone between formation level and 1.00 metre below the same. Such testing shall be undertaken in the dry season when the existing ground is theoretically at its maximum strength.
- (iii) The Engineer will establish, from the results of the testing in (ii) above and from the results of testing to establish the suitability of proposed borrow source materials what the final CBR values shall be for pavement design purposes, and shall thereafter confirm whether any adjustments are required to the provisions shown in the Contract Documents.
- (iv) The Engineer reserves the right to amend the extents of surface treated pavements as given in (iii) herein at any time during execution of the Contract.
- (v) Where borrow material or excavated suitable material with a CBR greater than 15% is available the Contractor shall reserve the same for use in the top 300 mm of fill and/or for use when the existing sub-grade CBR is less than 8% and the Engineer instructs its removal and replacement

5.2 BRIDGE AND DRAINAGE DESIGN

5.2.1 Hydrologic Parameters for Hydraulic Design

1) General

The design criteria for determining the classification for bridge and box culverts has been done based on the discharge and capacity of culvert, with maximum of 3 cells 3.5x3.5 m(HxW). If greater than this the cross drainage shall be considered as a bridge.

The hydraulic design of drainage structures for road proceeds by first undertaking a hydrological analysis of a particular drainage area. This is then followed by quantifying the volume of discharge, then by hydraulic design of structure appropriate for the determined discharge. The most common method makes use of the Rational Formula for estimation of discharge from the watershed or catchment area. In the hydraulic analysis, Manning's equation is commonly used for proper estimation of flow rates in a given structure.

The hydrologic and hydraulic analyses require secondary and base data such as topographic maps, land use information, water use information, rainfall and high water marks for waterways, if available. The computations of the structural works will form part of the engineering design of the project, which will be the basis for detailed plans and specifications.

5.2.2 Method of Calculation

1) Hydraulic Computations for Bridge Design and Box Culvert Design.

(i) Design Flow Computations.

In general, meteorological conditions and basin characteristics are the major hydrological variables that affect flow peaks and both must be considered in each study for determining the design flows. The following formulae have been used to determine design flood discharges:

Hydraulic formula of Manning:

$$Q = VA \quad (\text{m}^3/\text{sec})$$

$$V = \frac{1}{n} AR^{\frac{2}{3}} S^{\frac{1}{2}} \quad (\text{m}/\text{sec}); \quad R = \frac{A}{P} \quad (\text{m})$$

$$\text{Then} \quad Q = \frac{1}{n} A \left(\frac{A}{P} \right)^{\frac{2}{3}} S^{\frac{1}{2}}$$

Where:

Q = design discharge (m^3/sec)

V = velocity (m/sec)

A = cross-section of opened water way (m^2)

n = manning's roughness

R = hydraulic radius (m); $R = \frac{A}{P}$; p = wetted perimeter (m)

S = slope of stream bed or ditch (m/m)

Based on information obtained from the site by Surveyors, such as history of flooded levels given by DPWTs of Vientiane Capital and Vientiane Province, and the natural condition of rivers, geographic condition of project area, the design flood discharge (DFD) can be determined from that data, catchment area is very large cause of project road locates in flat terrain as described in Section 3.4.5, value of flood levels for bridge design are referred to record of history of flood and by interview of local residents. All proposed bridges are small and single span bridges across narrow streams

2) Hydraulic Computations for Culverts Design

(i) Flood Discharge Estimates.

Generally meteorological conditions and basin characteristics are the major hydrological variables that affect flow peaks and both must be considered in each study for determining the design flows. Normally the following formulae shall be used to determine design flood discharges:

The maximum water discharge shall be calculated by Rational formula:

$$Q = 0.278CIA, \text{ m}^3/\text{sec}$$

Where:

Q : Discharge in m^3/sec .

C : Run off coefficient is depending on the return period and watershed condition.

I : Rainfall intensity in mm per hours, for the duration corresponding to the time of concentration (T_c) of each catchment area.

A : Catchment area in Km^2 .

The time of concentration is the time period (duration) required for the rain water to reach the outlet from the most remote of the area, in hours. The formula used is:

$$T_c = \left[\frac{0.87L^3}{H} \right]^{0.385}, \text{ in hours}$$

Where:

L : the length of the catchment area, in Km.

H : the corresponding level difference in metre (m).

5.3 Bridge and Box Culvert Requirements and Design Standards

5.3.1 General

Substructures of the bridge are designed for safety, serviceability and constructability. Design starts with the determination of the required structural resistance to satisfy strength and with checks on service conditions using AASHTO Load and Resistance Factor Design (LRFD) based on theory of reliability and current statistical knowledge of loads and structural performance is used.

All loading conditions critical during the life of the structure are considered. This is followed by strength check of the entire member under factored loads using factored load factor design.

The following design stages are considered:

- Service: This condition refers to the load combinations related to the normal operational use of the bridge to control deflection and cracking.
- Strength: This stage is the basic load combination relating to normal vehicular use of the bridge to prevent failure.

5.3.2 Bridge Type and Spans

- 1) Bridge superstructure type: Pre-Stressed Concrete Girder I shape (PCI-Girder) with composite reinforced concrete deck
- 2) Superstructure spans: PC-I Girder 19m, 22m and 25m are used
- 3) Substructures: Due to less heights of piers, solid wall-type piers are proposed. Abutments are rigid cantilever type. All foundations are carried on precast driving piles foundations.

5.3.3 Design Loads

All the permanent and transient loads that are expected to be applied to the bridge during its service life are considered.

The permanent loads remain on the bridge for its entire life. These include the self weight of the truss, concrete deck slab, curbs, posts, railings, utilities, other dead loads and earth pressure.

Transient loads include gravity loads due to vehicular and pedestrian traffic, as well as lateral loads due to water, wind and earthquake.

Design loads are according to AASHTO LRFD Bridge Design Specifications 2007 (LRFD), as follows:

Dead Load: weight of all structural members, appurtenances and utilities.

Live Load (STD 3.7.6): AASHTO *HS 25-44 + 25% (HS-25)* lane loadings including impact 33% impact.

Longitudinal force (STD 3.19): Equal to 5% (*lane load + PL_M*).

Friction Forces (LRFD 3.13): Frictional resistance of sliding surfaces in bearings assumed equal to 10% of *superstructure dead load applied at abutments*.

Earth pressure (STD 3.20): based on backfill soil with $\phi = 30^\circ$, $\gamma = 18.0 \text{ kN/m}^3$ and active earth pressure K_a is based on Rankines earth pressure theory neglecting wall friction.

Buoyancy (STD 3.19): considered as uplift force acting on substructures below water level.

Force of stream current (STD 3.18.1). Velocity of water $V = 5 \text{ m/s}$ but checked with additional log and debris forces (LRFD 3.7.3).

$$P = 5.14 \times 10^{-4} \times C_D \times V^2$$

Where:

p = pressure of flowing water (MPa)

C_D = drag coefficient

V = design velocity of water for design flood (m/sec)

for log and debris forces, $A=3000\text{mm}$ and $B=14000\text{mm}$ are used.

Wind load (LRFD 3.15). Tributary areas of steel plate girder, slab and railings are used.

$$P_D = P_B \times \left(\frac{V_{DZ}}{V_B} \right)^2 \quad \text{where } V_{DZ} = 2.5 \times V_0 \times \left(\frac{V_{10}}{V_B} \right) \times \ln \left(\frac{Z}{Z_0} \right)$$

Where:

P_D = design wind pressure

P_B = base wind pressure

V_B = base wind velocity = 160 km/hr @ 10m height

Earthquake Force effects (LRFD 3.10): Substructures are designed for Seismic *Zone 2* ($0.09 < A < 0.19$) but using $A=0.19$ in the design. See Lao PDR Seismic Hazards map. Response Modification Factor (LRFD Table 3.10.7.1-1) with $R=1.5$ (essential bridges) for substructures but $R=1.0$ is used.

A response spectrum analysis is used using AASHTO elastic response spectra (LRFD 3.10.6) below.

$$C_{sm} = \frac{1.2 \times A \times S}{T_m^{2/3}} \leq 2.5 \times A$$

Where:

C_{sm} = elastic seismic response coefficient

T_m = period of vibration of m^{th} mode (sec)

A = acceleration coefficient

S = site coefficient

Combined load effects are determined according to load combinations specified in AASHTO LRFD.

In addition, minimum bridge seat widths (LRFD 4.7.4.4) at expansion bearings are designed with minimum

$$N = (200 + 0.0017 \times L \times 0.0067 \times H) \times (1 + 0.000125 \times S^2)$$

Where:

N = minimum support length (mm)

L = length of bridge deck to adjacent expansion joint, or end of bridge deck (mm)

H = for abutments, average height of columns, or pier height (mm)

S = skew of support ($^{\circ}$)

5.3.4 Materials

For reinforced concrete, the 28-day concrete compressive cylinder strengths are as follows:

Foundations, substructures and walls: 30 MPa

Girder: 40 MPa

Reinforcing steel are deformed bars conforming to AASHTO M31 *Grade 60* with minimum yield strength of 414 MPa .

5.3.5 Foundation Investigations

The soil samples and rock cores testing results and various recorded observations are recorded in the log of test borings. The results of the subsurface information are used to analyze the foundations for the bridge substructures.

5.3.6 Abutment Design

Abutments stems are analyzed and designed as cantilevers but wing walls analyzed as plates with fixed supports at footing and stem edges. Since abutments are on fixed bearings, lateral forces due to earth pressure and surcharge, bearing resistance at fixed bearings and earthquake forces (see below) are considered.

The Mononobe-Okabe Earthquake Analysis (LRFD A11.1.1.1) is used. Seismic active pressure coefficient,

$$K_{AE} = \frac{\cos^2(\varphi - \vartheta - \beta)}{\cos \vartheta \times \cos^2 \beta \times \cos(\delta + \beta + \vartheta) \times \cos(i - \beta) \times \Psi}$$

$$\Psi = \left(1 + \sqrt{\frac{\sin(\varphi + \delta) \times \sin(\varphi - \vartheta - i)}{\cos(\delta + \beta + \vartheta) \times \cos(i - \beta)}} \right)^2$$

$$\text{Earthquake force } E_{AE} = g \times \gamma \times H^2 \times (1 - k_v) \times K_{AE} \times 10^{-9}$$

Where:

k_h = horizontal acceleration coefficient

k_v = vertical acceleration coefficient

ϑ = arc tan ($k_h / (1 - k_v)$) (°)

g = acceleration of gravity (m/sec²)

γ = density of soil (kg/m³)

φ = angle of friction (°)

δ = angle of friction between soil and abutment (°)

i = backfill slope (°)

β = slope of wall to vertical(°)

Abutments are designed using California Department of Transportation Caltrans software WinAbut.

5.3.7 Foundation Design

The ultimate strength and serviceability of the bridge structure depends on its foundation. Subsurface investigations were carried out to determine the depth of rock, rock type and quality, soil types, soil strengths and groundwater levels.

5.3.8 Driving Pile Design.

Geotechnical resistance of bored pile is determined using, from the hydraulic analysis, scour depth at the piers surface.

AllPile software by CivilTech is used for lateral and vertical pile analysis with the following assumptions:

Zero friction is assumed in soils down to scour depths.

Only side resistance of rock is considered neglecting end bearing at pile tip. Rock strength analysis is based on Hoek-Brown procedures to determine rock cohesion. Rock geotechnical side resistance is based on unconfined compressive strengths of rock cores and rock jointing.

Shaft resistance in rock (LRFD 10.8.3.5.4b)

$$q_s = 0.65 \times \alpha_E \times p_a \times \sqrt{\frac{q_u}{p_a}} < 7.8 \times p_a \times \sqrt{\frac{f_c}{p_a}}$$

Where:

- α_E = reduction factor to account for jointing
- p_a = atmospheric pressure = 0.101 MPa
- q_u = uniaxial compressive strength of rock (MPa)
- f_c' = Concrete Compressive Strength (MPa)

Soil parameters such as soil unit weight (γ), angle of friction (θ), cohesion (C), modulus of subgrade reaction (k) and soil strain (E_{50}) are determined from correlations with SPT values in boring logs.

5.3.9 Design Stresses

The service load design method were as follows:

- Concrete Class 15 MPa, $f_c = 6.0$ MPa (Blinding Concrete)
- Concrete Class 20 MPa, $f_c = 8.0$ MPa (RC structures)
- Concrete Class 25 MPa, $f_c = 10.0$ MPa (RC structures)
- Concrete Class 30 MPa, $f_c = 12.0$ MPa
- Concrete Class 35 MPa, $f_c = 14$ MPa
- Concrete Class 40 MPa, $f_c = 16$ MPa (for bridge design)
- Reinforcement Grade 40 for mild steel bar
- Reinforcement Grade 60 for deformed bar

5.4 Concrete Structure Design

5.4.1 Pipe Culverts

Design has been made for installation of three types of pipe culverts; single, double and triple cell.

- The pipe culvert barrels have been designed as tongue and groove with sizes of 1000 mm diameter, and over in conformity with AASHTO M 170 M, Reinforced Concrete Culvert, Storm Drain and Sewer Pipe.
- For pipe culvert barrels with a minimum cover of 0.6 m shall be Class IV Wall B and with a minimum cover of 0.4 m Class V, Wall B.

5.4.2 Box Culverts

There are three types of box culverts: single cell, double cell, and triple cell.

- Box culverts have been designed for a minimum cover of 0.60 m and a maximum cover of 3.00 m. The minimum size is single cell 0.40mx0.40m and the maximum 3.50mx3.50m.
- Tables on the drawings give details, dimensions and reinforcement for all relevant sizes and types. These drawings are to be used when extending existing box culverts as indicated on the drawings. The existing culverts have many different and irregular sizes. The Engineer will confirm which standard type is to be adapted in each case.
- Inlet and outlet structures are separated from the box culvert barrels. The Engineer will confirm in each case which type is to be used and decide how the barrel and the inlet and outlet structure should be located to achieve a smooth waterway adapted to the site conditions with inlet and outlet channel excavation as necessary. The erosion protection will be decided at the same time as it may influence the layout.

5.5 Drawings

The Consultant studied ToR, reports and the condition of the existing structures. It has been proposed the following design standards;

- 1) ASEAN Highway Standards class II in level terrain and Urban Road Standard 4-Lne 2-Way Divided
- 2) Design Code: AASHTO LFRD
- 3) Seismic: zone 2, coefficient A = 0.19
- 4) Live load: HS-25-44 truck.

After the collection of field data, field investigations & survey, roads, bridges, structures, drainage and miscellaneous items such as bus stop, parking area will be designed. On this basis the following drawings will be prepared.

- Project location map
- General layout of road alignment map
- Road map
- Details of contour and co-ordinates system
- Technical notes
- Strip plans indicating the alignment of existing road edges and proposed road width, geometry of the road, location of structures, details of longitudinal profile indicating ground level, finished road level, gradient, location of reference to the bench mark and reference to chainage.

- Details of horizontal curves including super-elevation details
- Details of vertical curves
- Details of drainage
- Bridge structures
- Details of intersections
- Details of road signs, signal and their locations, road appurtenances and miscellaneous
- Road lighting
- Strip plans indicating location/relocation of utility services
- Standard drawings

5.6 Type of Structures and Requirements

5.6.1 Bridges and Culverts

In general, the design basis for existing and new bridges is as follows:

- 1) New bridges should have 16.0m (Min.) wide decks excluding footpaths on precast piled or spread footing foundations. The design live load for new bridges is HS 25–44 truck.
- 2) Existing bridges could not be widened due to existing substructures were simply constructed and more than 25 years old. Existing bridges are 7.0m wide decks excluding footpaths these bridges shall be visually assessed for possible need for other remedial work on the structure to meet the necessary design life. Bridges that are noticed to need additional loading test shall be done during construction phase.
- 3) Minimum footpaths 1.0m wide on one side of the structure are required for all bridges.
- 4) Proposed width of bridge are different as follows:
 - In 4-lane section: 16m - 22m width excluding centre median/space, in each traffic direction comprising of a 7m traffic lane 2m slow lane (in village area) and 2m sidewalk (including kerb and rail)
 - In 2-lane section: 8m width excluding centre median/space, in each traffic direction comprising of a 4m traffic lane and 2m sidewalk (including kerb and rail)
- 5) AASHTO LRFD Bridge Design Specifications (4th Edition, 2007), Load and Resistance Factor Design (LRFD), is used in the design of Bridges and Box-Culverts, but the AASHTO Standard Specifications for Highway Bridges, 1996 Load factor Design (LFD) is used for the design live load.
- 6) The design live load standard for new bridges is HS 25–44 truck for the actual structures involved in the project the controlling vehicle is one 400kN truck with three axles at 4.65-m intervals (44 kN + 178kN + 178kN) in each lane. For the dynamic impact considerations, some 25-30% should be added.
- 7) Due to recent earthquake activity in Sayaboury Province (23 February 2011), substructures are designed for Seismic Zone 2 ($0.09 < A \leq 0.19$) but using $A=0.20$ in the design. Response Modification Factor (LRFD Table 3.10.7.1-1) with $R=1.5$ (essential bridges) for substructures but $R=1.0$ is used, see hazard map in Appendix 6

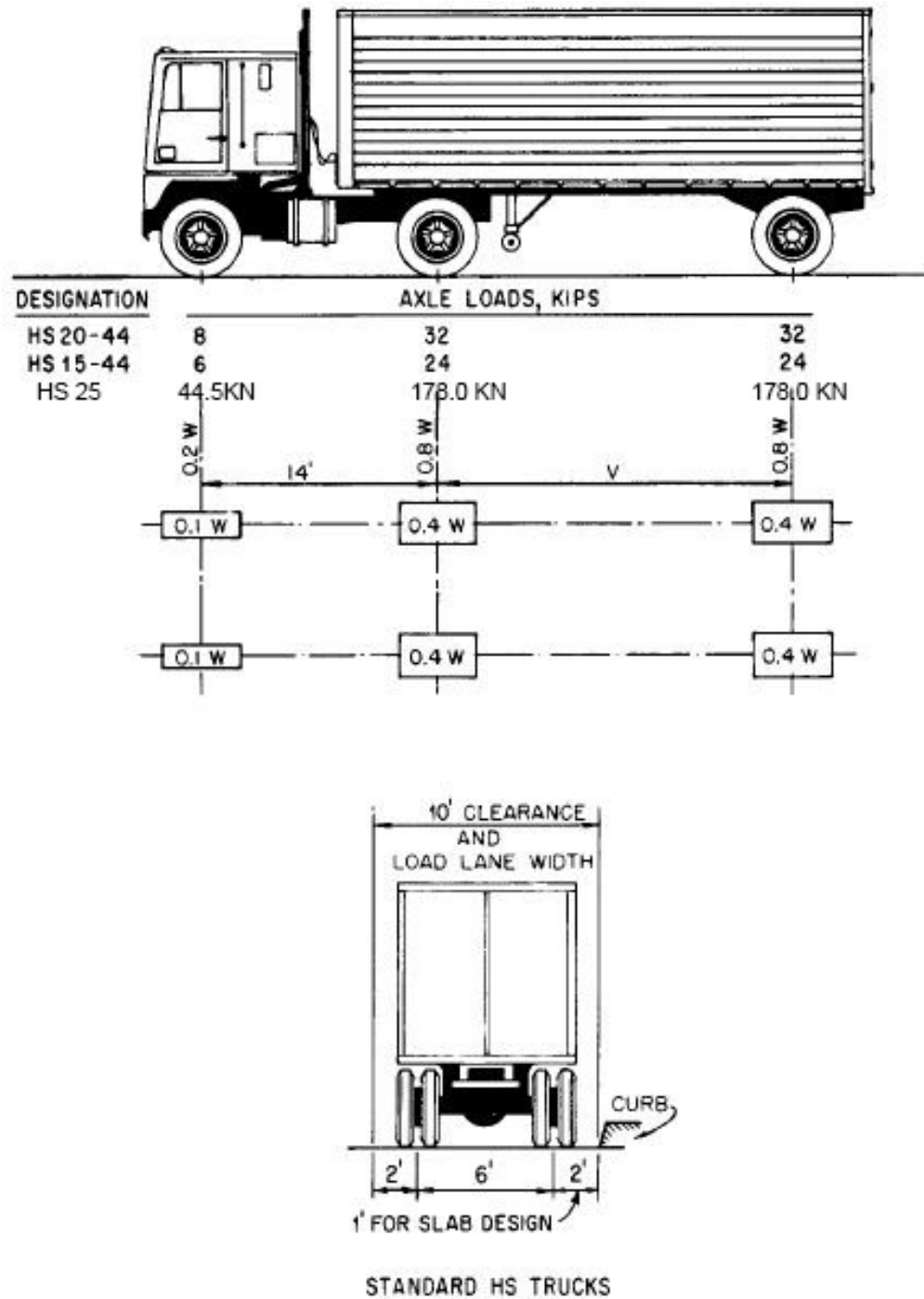


FIGURE 11.1 Standard HS loadings for design of highway bridges. Truck loading for ASD and LFD. W is the combined weight of the first two axles. V is the spacing of the axles, between 14 and 30 ft, inclusive, that produces maximum stresses.

Figure 3: HS-25 Truck

5.6.2 Superstructure

The following criteria will apply:

- 1) Precast PSC-I Girder has been selected as a superstructure type of small bridges. This has advantages of higher cost performance and easy construction and an appropriate span length which is applicable between 19m - 25m.
- 2) Precast PSC-I Girder can minimize the use of false work and other temporary support which constitute a considerable cost to the superstructure.
- 3) The typical cross sections of bridges are as shown in Appendix 5.

5.6.3 Substructure

Abutments have been designed with the shape of reverse T. This kind of abutment is economical at the height of 6~13m. Abutment type was decided after evaluation study with some alternatives as below.

Item	Reverse T type	Rear buttress type	Semi-gravity type
Features	<ul style="list-style-type: none"> •Economic at the height of 6m~13m •Ease of construction •Good post banking and compacting condition •Advantage in application to mountain or river crossing area 	<ul style="list-style-type: none"> •Economic at the height of 10m~20m •Difficult construction •Poor post banking and compacting condition •Applied to flat area, road and railroad crossing 	<ul style="list-style-type: none"> •Economic at the height lower than 6m •Ease of construction •Good post banking and compacting condition •Advantage in small river crossing bridge
Appropriate superstructure type	•Slab/Beam/Box	•Box	•Slab/Beam/Box

Soil condition of foundation bearing layer of the bridge has been considered with selecting foundation type which should be suitable for the transferred load of superstructure and soil conditions. Foundation type selection is as follows;

- 1) Topographic features and geological condition of the field : bearing depth 2~5m
- 2) To minimize the damages of nature and environment destruction.
- 3) Load due to characteristics of superstructure (vertical load, horizontal load, allowable settlement)
- 4) To minimize the design changes unexpected: review the topographical status and soil conditions.
- 5) Ease construction considering site condition.

- 6) Spread foundation under the water has the rock fill on the footing for scour protection. In case of bored pile design, the scour depths are assumed to be on top of rock at those locations.

5.6.4 Box Culverts

Inlet and outlet structures are separated from the box culvert barrels. The Engineer will confirm in each case which type is to be used and decide how the barrel and the inlet and outlet structure should be located to achieve a smooth waterway adapted to the site conditions with inlet and outlet channel excavation as necessary. The erosion protection will be decided at the same time as it may influence the layout.

There are two types of box culverts: single cell type and double cell type

Box culverts have been designed for a minimum cover of 0.60 m and a maximum cover of 3.00 m. The minimum size is single barrel 3.00m× 2.50m and the maximum double barrels 3.50m×2.50m.

Tables on the Drawings give details, dimensions and reinforcement for all relevant sizes and types. These drawings are to be used when extending existing box culverts as indicated on the drawings. The existing culverts have many different and irregular sizes. The Engineer will confirm which standard type is to be adapted in each case.

6. TRAFFIC SAFETY AND CONTROL DEVICES

6.1 General

The road traffic safety audit in this report was prepared with collected details from site inspection during August 2017. To make a road safety policy, strategy and project implementation schedule, it collates background information and existing road safety condition from the feasibility study and other relevant project documents.

6.2 Scope of Service for Road Safety Component

The Consultant will assist the provincial DPWTs to implement a road safety awareness campaign. The programme will be targeted to schools and communities adjacent to the road and be implemented during and after construction of civil works. The community road safety programme will increase local traffic safety awareness, improve the safety of children, and reduce traffic accidents related to pedestrians, children, animals, and drivers. The scope of work includes the following tasks.

- 1) Implementation of measures by adopting safety standards during construction period,
- 2) Installation of speed signs in settled areas,
- 3) Establishment and enforcement of speed limits,
- 4) Design and implementation of road safety education for children by preparing and testing educational materials, and training instructors to educate teachers using materials, and
- 5) Design and installation of roadside fences to prevent livestock and children from stepping onto the roadway. Determination of proper methods of fence construction and supervising standards during construction.

- 6) Design and installation of bridges for pedestrian crossing by over pass and side walk at community area such as schools and market area
- 7) Installation of raised median on 4-lane section to avoid head on collision is a high severity case of traffic accident
- 8) Design of Bus Bay and parking area where there is suitable space

6.3 Related Plan for Road Safety

6.3.1 National Lao Road Safety Strategy 2011-2020

The Lao National Road Safety Committee (NRSC) has defined Lao Decade Road Safety Strategy and Action Plan 2011 to 2020 is concerned with road safety and is aiming to reducing the loss of life and property by making more orderly, convenient and safe traffic situations. This Lao Decade Strategy is continued from previous Strategy 2005 – 2010.

To solve the accident problems, as in the past, the Ministry of Public Work and Transport (MPWT) has the main responsibility to draft the legislations, regulations and the law concerning road traffic. The Ministry of Public Security Police has the duty to inspect and enforce the regulations and laws including the duty of training and educating drivers.

To keep decreasing the accident rate, it is necessary to train more personnel, raise the budget allocation, and better the tools and the management method in relation with the actual situation. The said strategy plan shall rely on the outcome of the actual study of the accidents of the country and incorporate international experiences to overcome road accidents.

Previous Lao's decade road safety strategy concentrated on the following three items (or called 3E).

- Education,
- Enforcement by law and police,
- Engineering

6.3.2 The Road Safety Action Plan

The Lao Government has assigned the work for implementation of plan and identified the responsible sector for 15 main categories for implementation. The works as following:

Sector 1 : Coordination and Management of Road Safety.

Sector 2 : Road Accident Data Systems.

Sector 3 : Road Safety Funding.

Sector 4 : Safe Planning and Design of Roads.

Sector 5 : Improvement of Hazardous Locations.

Sector 6 : Road Safety Education for Children & Young Adults.

Sector 7 : Driver Training and Testing.

Sector 8 : Road Safety Publicity Campaigns.

Sector 9 : Vehicle Roadworthiness and Safety Standards.

Sector 10 : Traffic Legislation

Sector 11 : Traffic Police and Law Enforcement.

Sector 12 : Emergency Assistance to Road Accident Victims

Sector 13 : Road Safety Research.

Sector 14 : Road Accident Costing.

Sector 15 : Collaboration.

6.3.3 Description of Road Action Plan

For the first two years, the plan will be implemented only in Vientiane Capital City, in the mid-term, it will be expanded to other cities and national roads, and in the long-term it will be expanded nation-wide. Various sectors of the said action plan have been thoroughly studied, and comments have been incorporated with various concerned authorities such as the Ministry of Education, the Ministry of Health, the Ministry of General Security Police, the Capital City DPWT, the Capital City Traffic Police, the Friendship Hospital, the Lao Red-Cross, the experts from ADB, GRSP and Handicap International Organization. The study results of various sectors were coordinated by UNESCAP and donors and the results will be a part of the ASEAN Road Safety Projects.

6.3.4 Proposed Project Road Safety Road Features

Road safety should be considered in a comprehensive way through all aspects in the design of highways. The safety features that were used in the project road are as follows:

- 1) Provision of a wider (0.5 to 2 metres depending on proposed road standard) sealed shoulder and side walk in community areas
- 2) Provision of bridges for pedestrian crossing by over pass in community areas such as schools and market areas
- 3) Provision of Bus Bay and public parking area at road side where there is suitable space
- 4) Improvement of poor sight distances;
- 5) Improved horizontal geometry by providing curve widening at on all sharp curves;
- 6) Design and installation raised median for separation of traffic direction
- 7) Traffic Calming, Amber flashing where these should be provided;
- 8) Road signs such as warning, information and direction signs, especially at curves less than 50 kph and installation of chevron signs
- 9) Raised pavement reflectors and provision of rumble bars at centreline on small radius curves;
- 10) Lane Markings consist of centreline, edge line and pedestrian crossing;
- 11) Speed humps and/or rumble strip at the entrance of populated town area and through the towns;
- 12) Chicanes, physical traffic islands constructed on the shoulders to reduce speeds to the desired level, where the road passes through communities;
- 13) Traffic islands and channelization at key intersection; and
- 14) Guardrails provided on bridge approaches, box culverts and area where sharp curves, and high embankments

6.3.5 Road Sign and Marking

Road signs used in the project roads are classified into four types such as (i) regulatory signs, (ii) warning signs, (iii) prohibitory signs, and (iv) guide signs.

- Regulatory and prohibitory signs give drivers notice of traffic laws and regulations.
- Warning signs direct attention to condition of the road on or adjacent to a street that are potentially hazardous to traffic operation.

- Guide signs indicate road designations, directions/distances, village name, points of interest, and other geographic or cultural information.
- Road markings placed on the pavement, curb, or object to convey traffic regulation and warnings to drivers. The types of road markings proposed for this project are
 - road centrelines,
 - pavement edge markings to delineate separation of motor and bike traffic, and
 - pedestrian crossings.

6.3.6 Environment of Roadside

The existing traffic facilities on Road is very poor and lack of road signs in general. One most obvious omission and lack of consistency or uniformity is for the warning signs for horizontal curves. Up to 80% of the curves are without advance warning signs.

Similarly advisory speed limit signs have not been provided on the Road. There are no speed signs along this road.

Also there is a lack of adequate information signs which could indicate distances and destinations.

Another safety concern is that there are no delineation of the alignment and roadway. The concrete culvert walls and their head wall have not been painted so as to provide positive safety guidance to the road user. Guideposts have only one at each side and lack any retro-reflective material on them. Chevron signs have not been utilized on sharp curves so as to make night-time delineation more effective.

There are locations where there is a need to provide crash barriers/ guard rails such as sharp curves, high embankments and approaches.

There is a lack of adequate timely warning for locations, where they may be communities/villages ahead, and children crossing.

6.3.7 Improvement of Road Alignment

On the existing road alignment, the radius of curvature is too small and many accidents are caused by these conditions, 4 locations have been identified for proposed improvement as listed in the followings:

- KM 13+800
- KM 25+200
- KM 25+600
- KM 56+950

6.3.8 Pedestrians Crossing Bridges

Overpass pedestrians crossing has considered to provide at a large school locates beside the main road, market area, and other communities' area which has a lot of people cross the road. This project has designed to provide for six locations as follows:

- 1) KM 1+800, Phanghaeng Village
- 2) KM 4+730, Naxai Tai Village
- 3) KM 15+400, Songkhoua Kangsaen Village
- 4) KM 18+900, Song Peuay Village
- 5) KM 39+985, KM52 Market
- 6) KM 56+553, Phonesy Tai Village

6.4 Traffic Accidents Statistics

Traffic accident data statistics were collected from the National Statistic Office and the Consultant reported in Feasibility Study, the data is shown in table 9, 10, 11, and Figure 4 below:

Table 9: Number of Accident Year 2004 – 2013

Road No	District	Length on Project Roads (km)	Total Number of Accidents over last 10 Years											
			2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	Total	
13N	Sikhottabong	10.9	132	0	0	0	0	0	0	0	0	0	0	132
	Naxaithong	32.0	18	46	0	0	0	0	0	0	0	0	0	64
	Phonhong	37.2	444	459	523	518	408	242	269	170	357	108	3,498	
	Total on 13N	80.1	594	505	523	518	408	242	269	170	357	108	3,694	

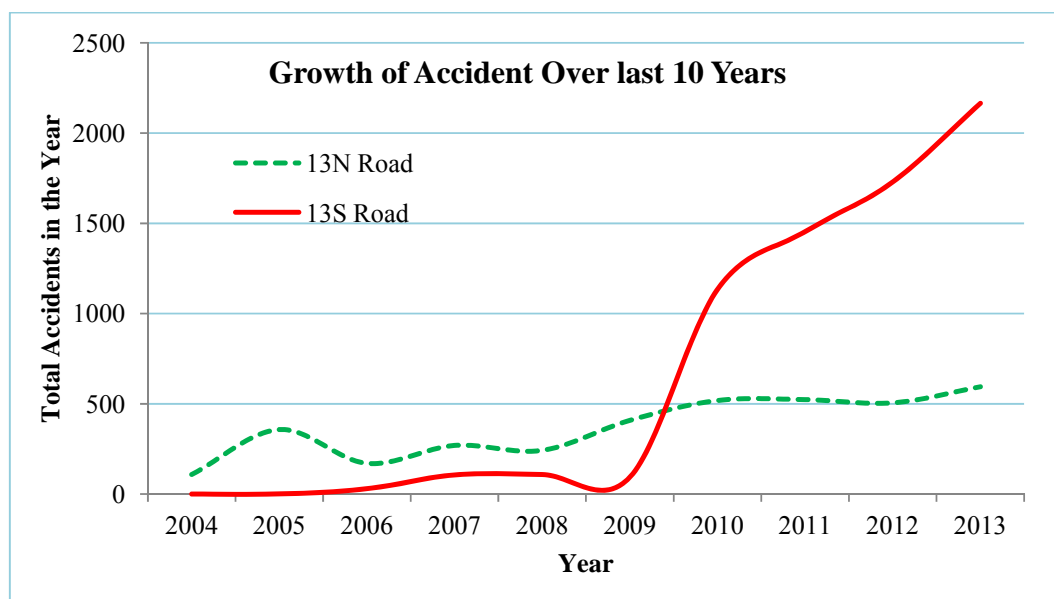
Source: Feasibility Study of Two Pilot PPP Road Projects in LAO PDR

Table 10: Number of Casualties Year 2004 – 2013

Road No	District	Road Section (km)	Length on Project Roads (km)	Accident Types				Total
				Fatal	Grievous	Light Injuries	Property Damage only	
13N	Sikhottabong	2.100-13.000	10.9	1	33	26	72	132
	Naxaithong	13.000-44.976	32.0	7	15	10	32	64
	Phonhong	44.976-82.168	37.2	153	661	959	1,725	3,498
	Total Accidents By Type			161	709	995	1,829	3,694
	Percentage (%) By Type			4%	19%	27%	50%	100%

Source: Feasibility Study of Two Pilot PPP Road Projects in LAO PDR

Figure 4: Road Accident Growth Year 2004 - 2013



Source: Feasibility Study of Two Pilot PPP Road Projects in LAO PDR

Table 11: Summary of Road Accident Year 2014 and 2016

Years	Provinces	No. of Accidents	Damaged Properties			Casualties		
			Minor	Medium	Cannot Used	Slightly	Severity	Fatality
2014	Vientiane Capital	1,500	1,207	1,774	37	1,023	298	195
	Vientiane Province	420	406	329	18	249	91	74
2015	Data not available							
2016	Vientiane Capital	1,554	1,113	1,987	56	1,000	380	261
	Vientiane Province	376	324	305	23	229	114	85
Increase/ Decrease (%)	Vientiane Capital	3.60	-7.79	12.00	51.35	-2.25	27.52	33.85
	Vientiane Province	-10.48	-20.20	7.29	21.74	-8.03	25.27	14.86

Source: Lao Statistics Bureau

According to Table 9 to Table 11, revealed the numbers of accident occurred and fatalities have increased due to increasing number of vehicles, except in the year 2014 to 2016 Vientiane Province number of accident was a little decreased, but number of fatalities still have increased.

As the rate of accident has been increased, there are corresponding increases in injuries and death to the travelling public.

Cost of damages has been increased as numbers of accident increased. It is expected that this trend will be continue. A pragmatic road safety plan is required to mitigate this trend.

6.5 Traffic Safety Plan for Project Road

6.5.1 Road Design Criteria

The survey for Project Road was done in August 2017. Data was collected on the existing alignment and the road condition. The purpose of widening the road is to improve the road condition for driving safety. The road passes through 52 villages and 8 schools. The summary of problems of road safety study is listed as below.

- Overall lack of road signs,
- Lack of warning signs on horizontal curves,
- Speed limit signs along with this road,
- Lack of adequate information signs indicating distances and destinations
- No delineations of the alignment,
- Lack of adequate timely pre-warning signs ahead of communities/villages and children crossing.

Road signs, guardrails and other road safety devices should be considered in design of this Project Road.

- Need guard rails
- Consider for bridges and culvert location
- Install for new road signs such as: Warning sign, Regulation signs, guide signs and etc...
- Safety issue on junction location
- Traffic calming and Amber flashing at village and school area
- Safety issue on sharp curves

6.5.2 Design and Location for Road Traffic Control

To design the road traffic control and signs, the purpose of design criteria is to produce the required traffic control device and traffic safety on dangerous sections.

The concept and process of design will be referred in strategy and specification. The main locations concerned in the design are;

- Curves with small radius,
- Bridges & culverts,
- Communities,
- Junctions and interchanges,
- Community areas, markets and schools.

6.5.3 Work Plan

Work action plan will be considered on two steps such as immediate action plan and long term action plan. Details and implementation plans are as follows;

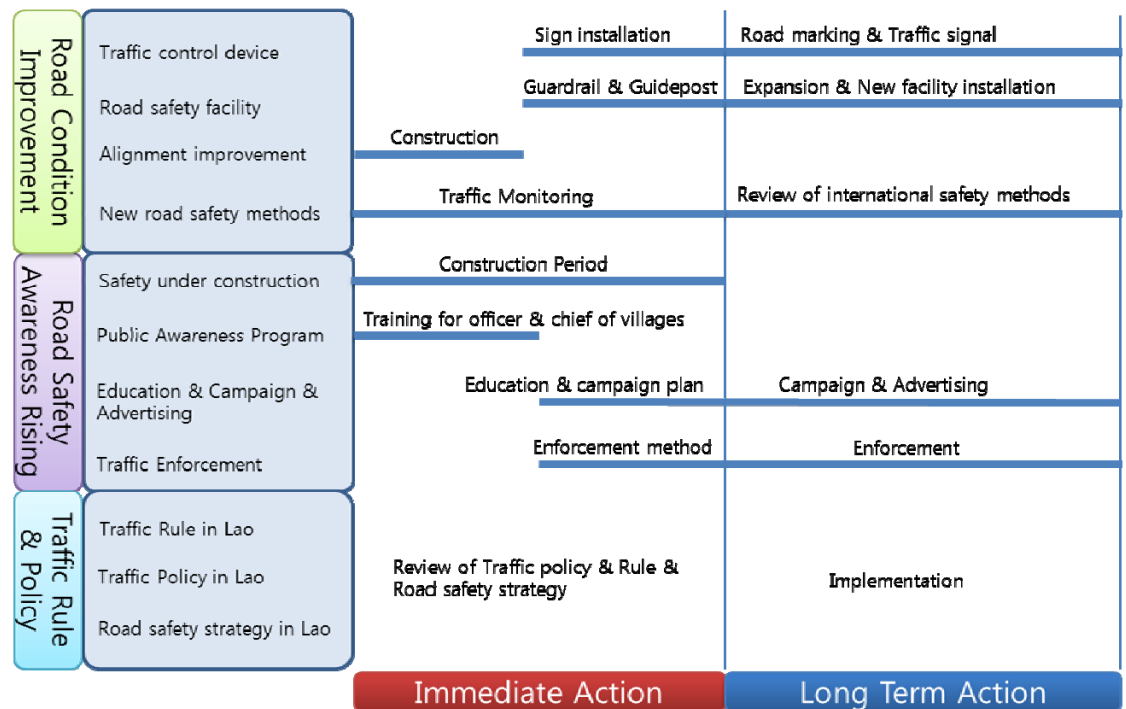


Figure 5 Action Plan

1) Immediate Actions Plan

The immediate action plans for road safety are;

- Identify the best standard and specification to apply on the project road. Review hazardous locations for resolving and reducing risk of accidents. Improve the inadequate location,
- Apply the strategy and standard to the recommence location for making the checklist for monitoring,
- Check the standard drawings for Road Traffic Control Device and Road Safety.

2) Long Term Actions plan

The long term actions plan is needed to coordinate with the DoT and local authorities to implement the road safety action plan for the project road, and also set up plans to work with MPWT for Awareness Campaign as specified in ToR. The schedule for RSA is following.

- Associate plan for road safety awareness programme with DPWT,
- Road traffic control and monitoring,
- Safety during construction phase.

6.5.4 Conclusions and Recommendations

- 1) As a result of the road safety in this design report conducted in the Project Road for traffic control devices improvement, detailed traffic safety features in each section shows slight differences, but overall safety in each section cannot be secured due to the lack of safety facilities and inappropriate application of regulation sign. It is required proper traffic controls and prevention facilities. For safety, attention should be paid to motorbike, and pedestrians using roads as a walkway.
- 2) Drivers expect the road situation/condition is based on visual signals of road and its surrounding environment. Therefore, it is necessary that same policy and facilities for road safety shall be applied in order not to confuse drivers. On main roads, it is important to ensure consistency of alignment characteristics and delineation by proper selection of traffic control devices and measures to improve road user behaviour.
- 3) The Consultant has performed reviews of various acceptable safety insuring methods and acceptable items at this stage. To ensure consistency and avoid dangerous situation in the future, the Consultant has checked the methods by planning suitable strategy or needed sections. Other major safety items for better design and consistency is the design of traffic calming measures in village zone areas.
- 4) The traffic control devices are designed according to Lao standards. The developed countries' criteria for the barrier and guidepost have been adopted in where the standards are not available.
- 5) A lack of traffic safety awareness and inadequate driver's behaviour can be improved by awareness rising measures such as educations, campaigns and public relations. They can reduce accidents in the long term view. Also the Consultant had reviewed various legal and political methods for reducing accidents. Traffic safety problems must be resolved by multilateral approaches, to get good results more effectively.

7. PROJECT IMPLEMENTATION

7.1 MPWT Project Management

In undertaking the Project, it is necessary for the MPWT-DOR to have adequate control for monitoring the progress of each of the packages. To effectively establish and maintain such control it is important that a separate the MPWT has established a Project Management Unit (PMU) to oversee the implementation of the projects. The PMU will be composed of personnel of MPWT-DOR and with specific responsibility for ensuring completion of the contracted works in conjunction with the construction supervision consultants for the Project. The MPWT has employed a consulting firm, consultant experts who will directly supervise the construction process of the contractors for each of the packages. A thorough checking of the designs shall be done by the supervision consultants and shall recommend approval only when found to be technically sound and acceptable. Following this assessment, the supervision consultant shall submit the approved designs and work program for approval for construction to the MPWT-DOR.

The DPWT in Vientiane Capital and Vientiane Province, where project components will be implemented, will provide counterparts to assist the project management unit. The team leader of the construction supervision consultants will be the Engineer's representative for the civil works, and will support the Project Management Unit.

7.2 Contract Packages and Construction Schedules

7.2.1 Contract Packages

This Road Project has split in two packages to minimize time for construction as defined by World Bank and MPWT, contract packages have divided as below:

- 1). Package 1: 19.40 km length, km 0+00 to km 19+400 four lanes section
This package 1 consists of three river bridges construction, eleven box culverts, thirty-three pipe culverts and 4 pedestrian crossing bridges
- 2). Package 2: 38.60 km length, km 19+400 to km 58+000 two lanes section including its transition

This package 2 consists of four river bridges one of them is new construction, five box culverts, ninety-six pipe culverts and two pedestrian crossing bridges

7.2.2 Construction Schedules

As required by World Bank and MPWT, all contracts shall be completed in 28 months, each package shall be divided in sub-sections and substantially complete construction at each sub-section in sequence as shown in Tentative Schedule in Appendix 10. The contract of this project is OPRBC mode, the payment will be made according to milestones (i.e. complete in sub-sections) as set forth in Particular Contract with the Contractor

7.3 Project Coordination

Project coordination will be undertaken by the Department of Roads (DOR). The construction supervision consultant team shall be headed by a Team Leader and shall direct the construction supervision of the project. Regular coordination meetings will be held and presided over by the DOR Project Coordinator.

Data and information sharing between all parties shall be encouraged for the benefit of the entire project and for the interests of the client.

Project construction meetings shall also be regularly set to coincide with accomplishment of major milestones and to be chaired by the Project Coordinator. During these meetings, accomplishments for each of components shall be presented along with project wide issues and concerns.

7.4 Construction Supervision Consultants

Most of the technical aspects pertaining to the construction supervision work shall be undertaken by a Team Leader. Reports pertinent to the Project shall be produced by the consultant and shall be submitted to the Project Coordinator, and upon verification will become part of the official documentation for the project. The progress reports and periodic reports shall be the responsibility of the Supervision Consultant. They shall spearhead the resolution of issues in the field and document any changes which will have bearing on cost and quality of the project. Monitoring systems and procedures will be established by the consultants in coordination with the PMU. The Supervision Consultant has defined scopes of work and will conform to the terms of reference of the Project.

The engagement of the Supervision Consultant shall commence prior the construction work is start. Procedural matters for the detailed engineering and construction shall be

established and will incorporate other parameters including environmental and resettlement issues. Prior to commencement, each contractor will be expected to submit its program of work to the supervision consultants for approval.

7.5 Implementation and Construction Program

It is recommended that;

- 1) The construction of the offices for the PMU and Engineer's Representative (Consultant) be based in the middle of Project Road.
- 2) The contractor's main camp should be located near the resident engineer's office area together with the accommodation and mess hall for the PMU and Engineer's representative.
- 3) All offices, accommodation and equipment will revert to the Client at the end of the Project.

Prior to the construction work starting, compensation for land acquisition and resettlement will be paid. This is a pre-requisite for the start of construction.

Throughout the construction period, the supervision consultant will be expected to provide advice to MPWT on matters affecting cost, quality, contractual obligations, and other related concerns.

8. DOCUMENTATION, BILL OF QUANTITIES AND COST ESTIMATION

8.1 Contract Documentation

The method of procurement of this project works for this project will an Output Performance Based Road Contract (OPRBC), the contract documents shall be managed by DOR. based on the World Bank Group procedure. The documentation is as follows:

- Specifications
- Drawings
- Other related reports (support data)

8.2 Method of Unit Cost Calculation

Two detailed unit cost method of calculation were used and compared, plant hire and haul distances

Based on the estimates of the borrow pits locations and quantities, haul distances were calculated and a unit rate built up including administrative costs, profit and tax.

In the plant hire method the unit rate was established using nearest plant hire rates for various machinery and method of operation and outputs that should be attained.

8.2.1 Unit Costs

These unit costs were used to calculate the project cost. The MPWT unit costs were used for the detailed costing of the project, where rates were not available the Consultants rates were used.

8.2.2 Bill of Quantities

The quantities in the Bill of Quantities for the project roads have been estimated with the limited data that has been processed.

The unit cost rates used for the cost estimates are based on MWPT unit cost, except which item is unavailable or unrealistic the Consultants rates were used

The work quantities for the pavement structure, which include the sub-base, base course, shoulders and sub-grade preparation, is considered uniform for each of the project roads for this preliminary cost estimate.

The drainage works quantities are also computed using survey results and estimated lineal extents for improvement or reconstruction. Bill of quantities of Project is shown in Appendix 9.

8.2.3 Project Cost Estimation

On the completion of the detailed design for the project roads, a Project cost estimate was prepared in separate volume.

The cost for the road pertains to that of earthworks, pavement structure, and drainage. Unit costs were used and applied to the entire project road. Information and quantification on earthwork requirements and drainage improvement were already considered and form part of this computation.

The work quantities for the pavement structure, which include the sub-base, base course, shoulders and sub-grade preparation, is considered uniform. The drainage works quantities are also computed using survey results and estimated lineal extents for improvement or reconstruction.

9. CONCLUSION AND RECOMMENDATION

The data that has been collected and analyzed was used in the estimation of costs for this Final Report. The following recommendations were taken into the account during the detailed engineering design:

9.1 Conclusion

- 1) The road structure design will be modified depending on the CBRs of the sub-grade values.
- 2) According to an official letter from DOR-MPWT confirmed about PCC Pavement type was selected for this project road. PCCP shall be used in final design
- 3) The existing drainage system shall be rectified and/or re-design to meet the requirement;
- 4) Where there are earth filled or any obstruction blocked at inlet & outlet of culverts and drainage channel shall be removed
- 5) In the village areas reinforced concrete ditches with cover were designed;
- 6) An eleven 11 tonnes axle load was used

9.2 Recommendation

The following works are proposed to take in the account in implementation stage and shall be conducted by the contractor

6) Inspection of existing bridges:

The Contractor shall conduct Bridge Inspection and Bridge Load Rating in accordance with AASHTO LRFR for all existing bridges to be remained

7) Test of existing pavement:

The Contractor shall conduct the following test of existing pavement

- Road surface roughness (IRI)
- Deflection test by Falling Weight Deflectometer (FWD), and evaluate existing pavement structure
- Test pits and sampling on the existing pavement and existing ground on proposed widening area
- Visual inspection and measurement of deteriorated area, and evaluation of deteriorated level in accordance with Method of ASTM-D4695, ASTM-D6433 or as given in ToR provided by the Client

8) Geological investigation at bridge construction site

This work consists of drilling and sampling at abutments by 2 boring holes per abutment or as directed by the Engineer

9) Hydrological study for risk reduction with climate change vulnerability particularly flooding area, and providing hydrological modelling

10) Animal crossing points

As proposed in ESIA Report, if it is agreed by DoR, MPWT the following works shall be performed by the Supervision Consultant and the Contractor

- Joint with local authorities to define animal crossing location as it is appropriately
- Design for construction of dry path facility along the stream and crosses under bridge at abutment on both sides for people and animal movement

APPENDIXES

Appendix 1	Road Alignment Lay Out
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8.2	Summary of DCP Test Results
8.3	Summary of Test Results of Material for Sub-Grade, Sub-Base, and Base Course
8.4	Summary of Test Results of River Sand, River Gravel, and Quarry
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9.1	Bill of Quantities and Cost Estimate for Contract 1
9.2	Bill of Quantities and Cost Estimate for Contract 2
Appendix 10	Tentative Schedules for Construction