APPENDIX IV: MATERIAL INVESTIGATION REPORT
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Abbreviations and Acronyms

ADB
Asian Development Bank

CBR
California Bearing Ratio

dh
Chainge

SASEC
South Asian Road Connectivity Project

DoR
Department of Roads

masl
Mean height Above Sea Level

TOR
Terms of Reference

AIV
Aggregate Impact value

ACV
Aggregate Crushing value

LAA
Los Angelos Abrasion test

RGoB
Royal Government of Bhutan

IEE
Initial Environment Examination

EMP
Environment Management Plan

Weights and Measures

Ha
Hector

km
Kilometer

m
Meter

mm
Millimeter

Mt
Metric Ton
Material Investigation Report for SASEC Road Connectivity Project

Project name: Detailed Design and Procurement of SASEC Road Connectivity Project
Project sub-head: Material investigation, sampling, testing and report production

Executive Summary

The material investigation is required by the ToR of the SASEC Road Connectivity Project as a part of “Detailed design, preparation of Bidding documents and Procurement”.

A total of two man-month input comprising of field and laboratory works and report production was allocated for the assignment. As per position based tasks/responsibility assignments, the Material Engineer is required to (i) Investigate, test, and define sources of construction materials; and (ii) Assess the sources of natural construction materials (e.g., quarry sites), carry out suitability tests, and prepare a materials report for the contractors’ information.

A total of 20 days was required to walk along the proposed alignment and accomplish the field work. The team comprised of four member including Material Engineer and an average daily labour force of 10 people.

The team walked all along the survey corridor and carried the field investigation works. The first trip was started from Nganglam side and about 35km was covered. The second trip was started from Deothang side to complete the balance 35km covering a total of 75km road length.

The field work comprised of identification of potential rock quarries, burrow pits materials, sand quarries, natural gravel material, digging pits at certain interval and collecting and sampling of material for further analysis in the material testing Laboratory.

The team made all possible effort to collect representative sample materials from the entire alignment. This was done to reduce the time taken to accomplish the task with the 2 man month period. The test pits/potentials quarry location are reflected along the proposed road alignment in the topography map of the area (Appendix 6). The alignment including the location of the quarries is also shown in the Google image map (appendix 5).

The laboratory testing work required thorough planning and continuous works in view of the limited test facilities. A total of 53 number of subgrade material have been collected along the road corridor of which 23 number sieve analysis, 51 CBR test, 30 Proctor compaction test, and a couple of Atterberg limit tests are conducted on the subgrade sample materials.
A total of 23 potential stone quarries have been identified of which 18 ACV test, 8 AIV test, 11 LAA test, 6 number 10% fines test, 6 number water absorption and specific gravity tests are conducted on the stone /boulders /natural gravel materials. Four potential sand quarries have been identified of which one is at Yangbari and the rest across the international boarder (in Assam).

The material samples were tested and analyzed in the APECS Test House, Thimphu, for various laboratory tests such as California Bearing Ratio test, Standard Proctor compaction test, Sieve analysis test, Linear shrinkage test and Atterberg limit tests on the subgrade and Blinding materials; ACV test, LAA test, AIV test etc on rocks and natural gravel sample and Sieve analysis, Fineness modulus and Silt content on sand sample.

The Material Engineer had acute shortage of labourer in the field particularly during first trip. During the first few days of the field works laborer demanded higher wages due to difficult working condition fuelled by continuous rainfall. The alignment was covered with thick bushes and no survey pegs could be traced. However, in the interest of the project, the material investigation team have put up all efforts and managed to complete the first part of the field works.

The time allocated for material investigation is less than required in view of the difficult terrain and its remoteness and the huge sample material to be tested and analyzed in the laboratory.
Chapter 1: Introduction

Background
The Royal Government of Bhutan has received a Grant from the Asian Development Bank (ADB) and it intends to utilize part of this grant towards the cost of the contract for consulting services related to detailed design in preparations for SASEC Road Connectivity Project, Department of Road, Ministry of Works and Human Settlements is the (DOR) executing agency for parts of SASEC Road Connectivity Project, i.e. (i) construction of about 74.5 km of the Southern East-West Highways between Nganglam and Dewathang section, and (ii) construction of Pasakha access road connecting Pasakha industrial area from an Indian boarder.

The material investigation is required by the ToR of the SASEC Road Connectivity Project as a part of “Detailed design, preparation of Bidding documents and Procurement”. A total of two man-month input comprising of field and laboratory works and report production is allocated.

After having given my CV for the post of Material Engineer, for the detailed Design and Procurement of SASEC Road Connectivity Project (hereinafter “Project”), Implemented by Department of Roads (DoR), MoWHS, and duly participated and awarded to Kyinkhor consultancy, I had agreed to work through APECS Consultancy in the capacity of Material Engineer (hereinafter “consultant”) for the purpose of material investigation, sampling, testing and report preparation and submission to the competent authority, as per the terms and condition agreed by both the party.

Based on the tour report submitted and agreed with the Team Leader, SASEC Road Connectivity Project, the Material Engineer along with his team performed the first field visit w.e.f. 10 to 19 August 2013 and the second field visit w.e.f. 26/9/2013 till 5/10/2013.

Scope of the work
As per table 2: Position based tasks/responsibility assignments, the Material Engineer is required to:

1. Undertake field visit to investigate, test, and define sources of construction materials;

2. Assess the sources of natural construction materials (e.g., quarry sites), carry out suitability tests, and prepare a materials report for the contractors’ information
Chapter 2: Work Approach and Methodology

General approach of the consultant
To successfully accomplish the task of the Material Engineer, the consultant prepared work schedule to cover both the field and the laboratory works.

The consultant had to plan for two field trips because the jungle clearance for the entire road corridor was not ready and in the absence of the jungle clearance material investigation would have been incomplete and illogical. Therefore, the field visit was taken up from Nganglam side and the subsequent from Deothang side.

Collection of documents, literature review and desk top study
Required documents such as google image showing the road alignment, topography map, the report on feasibility study were collected from the project team leader. Additional information was gathered from Messers Kyingkhor consultancy and the field surveyors for proper planning and field visit.

Literature review and desk top study
The google images, topography map and the feasibility study report were reviewed in order to gather first hand information. The actual length of the road alignment was noted and the number of sample to be collected and the frequency of the sampling was decided. The feasibility study report showed few potential material (stone) quarries. These were noted for further field verifications.

Meetings and Consultations
Several meetings and consultations with M/s Kyingkhor consultancy and the team leader involving the employer were attended well before commencement of the assignment. It was decided that the material investigation should closely follow the detailed road corridor survey works. This was to ensure that the work force required to clear the jungle was minimized. It was also agreed that the material investigation should start from the month of May 2013. However, the program initially envisaged and planned could not be followed due to serious labour shortage faced by the main consultant- M/s Kyingkhor consultancy in the field and got deferred till end of September 2013. There was several followup and consultation on this front between the Material Engineer, the team leader and the project coordinator until the program was finalized by the end of September 2013.
Chapter 4: The Field Visits

Alignment Reconnaissance
The Material Engineer and his team comprising of three technicians walked along the existing as well as new alignment from Nganglam till a km 37 in between Chokorling and Khalasho. The objective was to plan the subsequent detailed material investigation, to assess number of labour required for pit digging, material sampling and transporting the same to the nearest road head. After carrying out this exercise detailed material investigation work commenced.

Sample collection
The Material Engineer along with the team walked along the existing road from Nganglam zero point to 16th km of Nganglam to Chhokorling farm road. Stone quarries including naturally occurring materials were identified and mapped along the existing road. The sample collection was carried along the detailed topography survey corridor. Sample for CBR test, proctor compaction tests, sieve analysis were collected by digging pits of 1.0-1.5 m deep. Representative samples of subgrade was collected. Similarly, potential stone quarries, natural gravels quarrries were identified and their locations identified using hand held GPS.

Similarly, the team walked along the proposed road alignment (new alignment) from Yarjewong to past the Chokorling area and identified/mapped potential stone and natural gravels quarry locations. Pits were dug from the sub grade level /hill side slope to collected subgrade material for laboratory testing and analysis.

The team managed to collect sample materials upto 3-4 km past the Chokorling Telecom tower, located at about 32 km. In other words a total length of about 35 km was covered from the Nganglam side. The maps showing sample collection locations and pictures of field work /field investigation are attached herewith.

The sample materials were transported from all along the road alignment and was stacked at Nganglam. M/s Kingkhor Consultancy, lifted the sample materials to Thimphu for laboratory analysis on August 30, 2013.

Field tests and investigations
Field tests such as Field CBR using DCP and field density tests were conducted at few locations. Sample materials from the potential stone quarries were collected along the road as well as from uphill side of the road. Geological hammer was used as guide to note the mechanical strength of the stones and boulders and those having reasonably good strength were sampled for detailed laboratory testing and analysis. Pits were dug from the sub grade/hill side slope to collected subgrade material for laboratory testing and analysis. The sample materials collected were stored at certain locations by using manual labour as well as using private transport. GPS points were recorded and photographs were taken from those locations where sample have been collected and stones quarrries identified.
Chapter 5: Laboratory test works

Testing of material sample
The material samples were tested and analyzed in the APECS Test House, Thimphu, for various laboratory tests as follows:

On the sub-grade and blinding materials sample
1. California Bearing ratio test
2. Standard Proctor compaction test
3. Sieve analysis test
4. Linear shrinkage test
5. Atterberg limit tests

On the stone quarry/Natural Quarry materials
1. Aggregate Crushing Value (ACV) test
2. Los Angeles Abrasion (LAA) test
3. Ten percent fines test
4. Aggregate Impact Value test
5. Water absorption and specific gravity tests

On sand quarry samples
1. Sieve analysis
2. Fineness modulus
3. Silt content
4. Bulking of sand

The laboratory testing, analysis and report preparation is completed by 31 October 2013.

Laboratory tests, results and analysis

Sub-grade materials

California Bearing Ratio
The California Bearing Ratio test is conducted to ascertain the bearing strength of the proposed sub grade. The CBR in combination with the expected traffic intensity of the proposed road and other parameters shall be used to design the road pavement thickness (comprising of capping layer, the Sub-base, Base course and the Asphalt layer).

The summery of the CBR and the detailed test report is in Appendix V.
**Standard Proctor Compaction**

The standard proctor compaction is carried out to study the degree of compaction that could be possibly achieved on the in-situ sub-grade material. According to K.B. Woods following indicates value of the sub grade material mainly soil:

<table>
<thead>
<tr>
<th>Density (kg/m$^3$)</th>
<th>Soil Engg. Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000 &amp; above</td>
<td>Excellent soil</td>
</tr>
<tr>
<td>Between 2000 - 1900</td>
<td>Good soil</td>
</tr>
<tr>
<td>Between 1900 – 1650</td>
<td>Fair soil</td>
</tr>
<tr>
<td>Less than 1600</td>
<td>Poor soil</td>
</tr>
</tbody>
</table>

The Sub-grade material tested for the proposed Nganglam –Deothang NH falls in the range of fair to good category indicating that the sub grade soil would yield reasonably good degree of compaction if proper compacting equipment are deployed during the preparation of subgrade. There are, however, weak stretches having black soil where the pavement designer is required to review the both CBR as well as proctor compaction result to make provision for the capping layers. Generally, compacted/consolidated subgrade should have CBR of > 6 for construction of sub grade. Otherwise, a provision of capping material of one or more layer, total thickness consisting of 200 to 300 mm is required to strengthen the Sub-grade prior placement of any pavement layers. The summery of the Proctor compaction and the detailed test report is Appendix V.

**Material gradation (Sieve analysis)**

The grading of the sub grade material including naturally occurring material was conducted with the view to find the following:

- That whether the naturally occurring material could be used as sub-base materials with some modifications.
- That whether the subgrade material has the grading envelope acceptable as subgrade material.

The summary results are in Appendix V. The sieve analysis result shows coarse soil matrix mainly sand soil with completely weathered rocks.

**Linear shrinkage**

Sub grade material comprising of black clay and loam are subjected to shrinkage properties. Shrinkage soil if found on sub grade along the alignment should be treated appropriately to minimize or avoid shrinkage of sub grade. Similarly, soil having excess of shrinkage properties shall be avoided as blinding materials. Therefore, black clay and other soil which appear to have appreciable linear shrinkage was collected from along the alignment at couple of location and analyzed in the laboratory for the linear shrinkage. It was noted that although the soil was black the linear shrinkage was within the acceptable limit.
Blinding material

Blinding material quarries were identified at couple of places along the existing road as well as along the proposed alignment. There are not many location were ideal blinding material is available. Summary results of the linear shrinkage and Atterberg limits are attached in Appendix V. Details of quarries are shown in the alignment map.

Stone Quarry Materials

Potential stone quarries were identified along the alignment. These are marked in the google map attached. The summary of the test results are in Appendix V. Following tests were conducted on the material sample collected from the proposed quarries along the alignment.

1. **Stone / Aggregate crushing value test (ACV):** These tests are required to check the crushing strength of the rocks. The requirement should confirm to the following requirement as per IS 2386 –part IV.
   - 45% for cement concrete other than wearing courses
   - 30% cement concrete wearing course such as runways, roads and pavements
   - 40% for sub-base (WBM road)
   - 30% for base course (-do-)
   - 30% for surface dressing

2. **Stone/aggregate Impact value (AIV) test:** These tests are required to ascertain the pounding impact due to dynamic moving traffic. The results should confirm to the following requirement as per IS 2386 –part IV.
   - <10% : exceptionally strong
   - 10 – 20%: Strong
   - 10 – 30% : Satisfactory for road surfacing
   - 30% for cement concrete sub-base and other works
   - 31 – 35%: Suitability to be decided in conjunction with other test parameters
   - >35% : Weak for road surfacing

3. **Los Angelos Abrasion (LAA) test:** LAA test is conducted to check the wear and tear properties of the rocks /stone aggregates. The test is simulated to field condition of wear and tear in the laboratory. The results should confirm to the following requirement as per IS 2386 –part IV.
   - Water bound Macadam (WBM) sub-base course 60%
   - i. WBM base course with Bituminous surfacing
ii. Bituminous Macadam base course  
iii. Built Up spray grout base course  50%

3. i. WBM Surfacing course  
   ii. Bituminous Macadam Binder course  
   iii. Bituminous penetration macadam  
   iv. Built up spray grout binder course  40%

4. i. Bituminous carpet surface course  
   ii. Bituminous surface dressing, single or two coats  
   iii. Bituminous Surface dressing, using precoated agg  
   iv. Cement concrete surface course [as per IRC]  35%

5. i. Bituminous/asphaltic concrete surface course  
   ii. cement concrete pavement surface course [ as per ISI]  30%

4. **Ten Percent Fines test**: This test is determines the percent fines produced by applying a load of 400 kN for about 10 minutes. This test help to check if the stone aggregates to be used for wearing course surface has adequate strength to resist the crushing affect under dynamic or static load.

5. **Water absorption and specific gravity test**: These tests are conducted to check if the stone used for pavement construction are dense, compact and that the water absorption is within the acceptable limit, and are particularly useful to judge the quality of the material for bituminous works.

6. **Grading on naturally occurring gravelly materials**  
The naturally occurring materials were collected from number of locations along the existing road and well as from the proposed (new) road alignment. The materials were analyzed for grading envelope among other tests to confirm if these materials could be used as sub-base materials. The results are attached under Appendix V.

**Sand Quarries**

Sand is required for all road construction works. Therefore, the material investigation included identification of sand quarries along the road alignment as well as in the vicinity of the project area. Potential sand quarries are identified at the following locations:

1. Yangbari: Yangbari is about 30km away from Nganglam. The quarry area has been identified at about 37 km from Nganglam although some sand could be also sourced from Km 25 from Nganglam towards Yangbari. The sand at Yangbari is of acceptable quality although it is fine to medium sizes.
2. Barpeta: Another sand quarry is identified at Barpeta about 10km from Nganglam. The sand available at Barpeta is fine and contains appreciable amount of silt content. However, after washing it could be used for construction.

3. Pagla Nadi and Bada Nadi: Sand is sourced by Bhutanese contractors and builders from *Pagla Nadi* or *Bada Nadi* in Assam. It has been learned through interview and discussions with the builders that there are about 5 to 6 suppliers based at Samdrupjongkhar for the supply of stone chips and sand for eastern Bhutan. The sand sample were collected from S/Jongkhar to analyze the suitability and the results are appended at appendix 3. In general it has been found that both sand and stone chips imported from *Pagla Nadi* and crusher plant in the vicinity meet the requirement in terms of quality. The results are attached in Appendix V.

4. Stone crusher plant: A private stone crusher plant is identified at 5km away from Nganglam town. It has been learnt that the crusher plant has capacity of producing > 50MT of stone chips per day. Should the project require additional stone chips from the project existing crusher pant could meet the requirement.

A crusher plant is also coming up at Narphu, 80km from Samdrupjongkhar. It has been learned that a private crusher plant is in the process of establishment. In the event that, material are not adequate for the project along the alignment or should the contractor decide to procure stone chips instead of establishing their own crusher plant, the materials (stone chips and crushed rock dust) could be sourced from the proposed Narphu crusher plant.
Chapter 6: The Problems and the Constraints

Logistics and labour
The Material Engineer had acute shortage of labourer in the field. The Labour Manager could not be found in the field as agreed between Material Engineer and M/s Kyingkhor Consultancy. During the first few days of the field works laborer demanded higher wages due to difficult working condition fuelled by continuous rainfall. Further, due to substantial time gap between the detailed survey and the material investigation survey the alignment was covered with thick bushes and no survey pegs could be traced. However, in the interest of the project, the material investigation team have put up all efforts and managed to complete the first part of the field works. Logistics was a problem as there are no villages near the proposed road alignment at many stretches of the proposed alignment particularly between Reshore to Khalasho, Khalsho to Chokorloing and chokorling to Yarjewong. These problem necessitated the team to walk for long hours to reach to the worksite and back to the place of halt to nearest villages.

The second field visit for material investigation and sample collection, as approved by the team leader, was performed from Deothang side w.e.f. 26 September till 5 October 2013. The time gap between the first field visit and the second visit was maintained owing to the fact that laboratory works could only be started almost after 20 days of the field visit due to delay in receiving the sample materials from the field. Further, the survey corridor was not cleared throughout and it was not possible to take up the material investigation works without jungle clearance.

As per the agreement M/s Kyingkhor Consultancy, the main Consultant for the SASEC Road Connectivity project, is required to transport the sample material from the field of investigation to the material testing laboratory in Thimphu as soon as the field investigation is over. The material samples were delivered in the laboratory by 30 August 2013 only. However, the sample material collected during the second visit were lifted by the team in their back journey to Thimphu and the samples reached to material testing laboratory in Thimphu timely.

Weather conditions
The weather condition during first field visit was terribly bad. There was rainfall and cloudy days most of the time. The material samples got wet and transporting the same to the nearest road head was an uphill task. Labour preferred to carry out pit digging and sampling rather than transport the sample material as headload to the road side. However, the second field visit was comparatively better as labour strength was much better and the weather was good except rains couple of time.

Limited laboratory test facilities
Due to limited test facilities initiating test for all material sample in the laboratory was not possible. This required meticulous planning for testing. The time was limited and number of sample required to be tested were many. Therefore, with support from the team leader and
the project coordinator, SASEC Road Connectivity Project, few apparatus such as CBR mould and sample trays were burrowed from the existing DOR laboratory. The CBR mould helped to expedite the CBR tests as this test is time taking.
Chapter 7: Conclusions and recommendation

- The material investigation and testing is expected to provide adequate information to the designers particularly the pavement designer.
- The CBR values are as low as 3.5% and as high as 30%. The designer may chose an average value of 6.5% to 8.5% for the purpose of pavement design.
- The compaction properties of the sub grade soil is generally fair to good and not excellent as per K.B. woods. Therefore, use of vibro-roller and such other compaction equipment shall be made mandatory during the implementation.
- There are number of natural gravel quarry identified all along the road alignment. However, these materials cannot be used as it is. Therefore, use of screener is recommended for selecting the required sizes of gravel as GSB materials.
- Potential stone quarries have been identified along the alignment for GSB and WMM works. Some of the quarries identified in the feasibility study could not found along or nearby the alignment. The quality of material particularly for the asphalt concrete and concrete works may not be suitable. Therefore, material may have to be imported from the nearby private crusher plant located in the region.
- Potential sand quarries have been identified at Yangbari, 37 km from Nganglam; Barpeta(Assam) 10km from Nganglam and Pagla Nadi and Bada Nadi (Assam). The quality sand is found to be within the permissible limit for concrete and masonry works.
References:

1. Feasibility study report of the SASEC Road Connectivity project, 2012
2. Topography map and google images of the proposed road alignment
5. The code of practice for material testing as per I.S. 2386 and I.S. 2720
PHOTOGRAPHS OF FIELD VISIT, SAMPLE COLLECTION AND TESTING

Photographs (glimpses) taken during the field material investigation

Photo 1: Subgrade sample being collected

Photo 2: DCP test under progress
Photo 4: Natural gravels being collected for suitability  
Photo 3: Pitting done for material sampling tests

Photo 5: Technicians continue to work in the absence of adequate labour at Yarjeyong
Photo 6: Base of rock cliff along Muru ri- A potential stone quarry identified

Photo 7: Labour carry sample from thickly grown stretch at Yarjegong area
Photo 8: Studying the possibility on the use of Scree materials from along the proposed alignment at Yarjeyong

Photo 9: Stacking sample at road site at Yarjewong area
Photo 10 & 11: Thick bush along the alignment hampers smooth conduct of material investigation

Photo 12: Material investigation team passes through telecom tower at Chhokorling
Photo 13-14: Above and below-Material investigation past the telecom tower of Chokorling

Photo No. 15
Following are the glimpses of the field investigation pictures during the second field trip of the material Engineer.

*Photo 16: Identifying Potential Blinding Material at Rishor area*

*Photo 17: Pit digging at Km 67.5km*  
*Photo 18: Pit digging at 62.5km*
Photo 19: Traversing through the proposed alignment

Photo 20: Pit digging in progress at Km
Photo 21: Planning for the days work

Photo 22: Taking a break after hard work
Photo 23: Journey continues to Khalasho from Rishore

Photo 24: Pit digging in progress at 41 km in Khalasho area

Photo 25: Team heading towards Chhokorling area from Khalasho
Photo 26: Pit digging in progress approx 4 km after Chholorling telecom tower towards khalasho

Photo 27 & 28: Team trying to identify a potential stone quarry after Khalasho
Glimpses of the laboratory works

Photo 29: Back journey to Rishore with sample material

Samples being prepared in the laboratory for various tests
Professor (Dr.) Kishan teaching the tricks of trade for plastic limit test

Shrinkage test being cured
Laboratory Engineer conducts shear test

Proctor compaction test in progress

CBR test in progress
CBR sample under soaking tank

Concentration leads to better result: Technicians busy with various tests
Location of sample collection sites along the road alignment.
Location of sample collection sites in Topographic map.