6 Reference

6.1 Technical Notes of Meeting with ERA

Study for Route Selection in Debre Markos
under the Project for Rehabilitation of Trunk Road, Phase IV

1. Background

Detailed design for the study section (L=65km) between Dejen and Debre Markos had already been finished by HEC under ERA. According to the final detailed design report, the number of affected houses along the study section goes up to 159. This number is categorized in category A of the Environment Guideline of World Bank and JICA. In case of category A, it is necessary to consult and get approval of the JICA Advisory Committee on the Social and Environmental Issues. Consequently, this procedure may affect the implementation schedule for the Project causing delay and it is convenient to minimize the number of affected houses by selecting the best suitable route in Debre Markos to realize the planned implementation.

2. Comparison of two Routes

Outline of Alternative Routes in Debre Markos

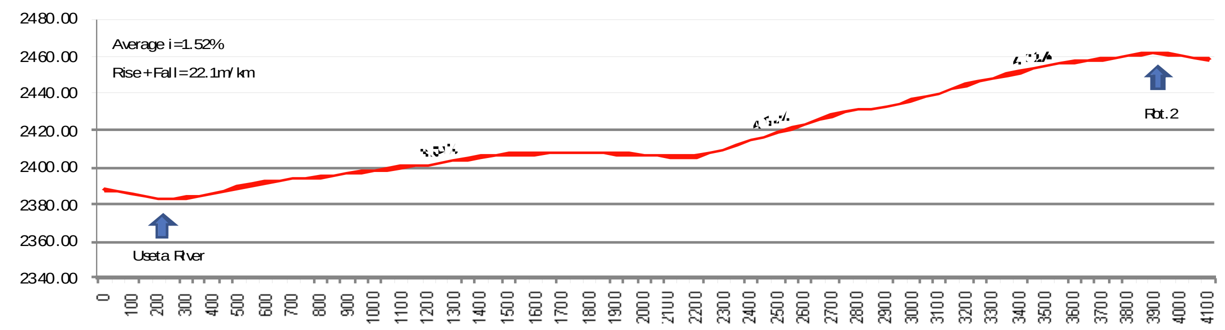
Alt.1: DD Route by HEC (Blue)
At entrance of Debre Markos, it diverts from existing A3 to unpaved town road and rejoins A3 in the city center via two new roundabouts.
Length: 4,100m
No. of Bridges: 2
Land Use: Residential and Commercial
Road Width planned by DD = 21.5m

Alt.2: Existing A3 (Red)
Existing A3 in Debre Markos is paved.
Length: 4,100m
No. of Bridges: 1
Land Use: Residential and Commercial
Road Width: See "4. Impact to Social Environment".

Fig.-1 Outline of Each Alternative

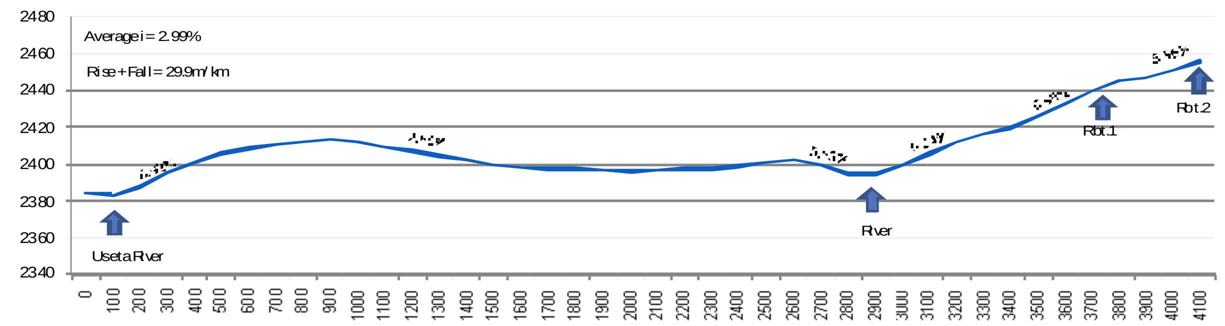
3. Evaluation from engineering point of view

(1) Vertical and Horizontal Alignment



Average I = 1.52%, Max. I = 4.52%, Rise and Fall = 22.1m/km

Reduction of risk of traffic accident will be expected by installation of road safety facilities.



Average I = 2.99%, Max. I = 6.93%, Rise and Fall = 29.9m/km

Increse of risk of traffic accident will be a matter of concern at two right-angled turns in densely populated area of Debre Markos Town.

Fig.-2 Comparison of Characteristics of Each Alternative

2

(2) Disadvantages of Horizontal and Vertical Alignment.

As mentioned earlier, the DD route by HEC passes two new roundabouts located within a congested town area before connecting to the existing A3. However, the elevation difference of A3 and DD route at connecting point at Rbt.2 is approximately 3m. This will result in a steep grade of more than 10% at Rbt.2 and more than 7% at Rbt.1. Consequently, these poor geometric features will constrain heavy trucks that commonly use this route. In addition, unexpected affected houses will likely be increased with the construction of roundabouts.

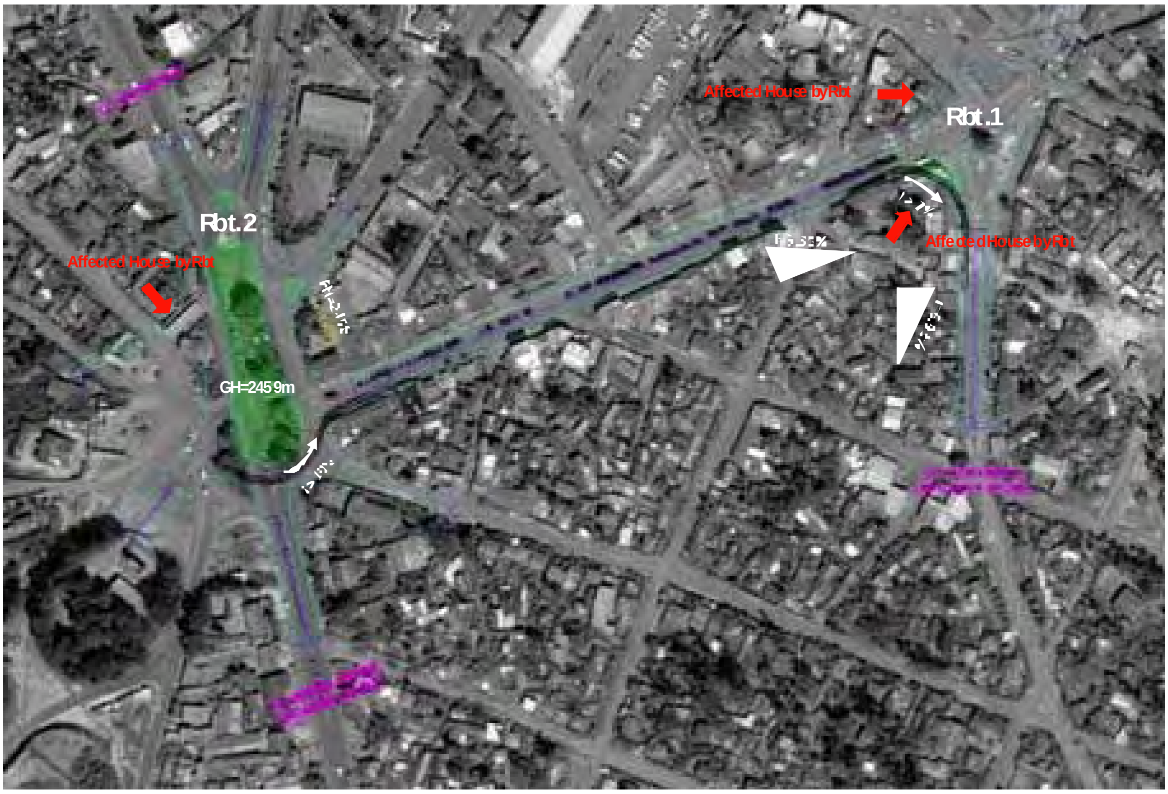


Fig.-3 Issues of Connecting Point to existing A3

(3) Summary of Comparison of the existing A3 (Alt.2) and DD Route by HEC (Alt.1) in Technical Aspect

Table-1 shows that rehabilitation of existing A3 (Alt.2) is more superior than HEC (Alt.1) in all items of technical aspect.

Table-1 Comparison of two alternatives in technical aspect

	Alt.2 Existing A3	Alt.1 DD Route by HEC
Alignment		
(1)Length of route	4.1km	4.1km
(2)Gradient (average)	1.52%	2.99%
(3)Gradient (max.) Inclination	4.52%	6.93% Over 7% at Rbt.1 Over 10% at Rbt.2
(4)Flatness (Rise and Fall)	22.1m/km	29.9m/km
(5)Number roundabout	0	2
(6)Turning	0	2 intersections at a right angle
(7)Radius of curve (min)	200m	30m
Traffic condition & traffic safety		
(8)Disturbance by transit traffic & local traffic	Less	Heavy
(9)Traffic jam	Less	Heavy and frequent due to (3), (5), (6), (7)& (8)
(10)Vehicle Speed	Good	Slow due to (9)
(11)Traffic safety	Good	Poor due to (8)
(12)Comfort	Good	Poor due to (4) & (9)
(13) Transportation cost	Low	High

4. Impact to Social Environment

1. On-site Investigation of the alignment of ERA/DD

(1) Date

- 20th September 2010

(2) Members

- ERA; Mr.Gashaw and one highway engineer
- HEC; Survey engineer
- Debre Markos Municipal; One engineer
- JICA Study Team; Dr.Tatsumi, Mr.Takagi, Mr.Mizuno, Mr.Nemoto

2. Number of Affected Houses

In case the existing route A3 alignment is used in Debre Markos, the number of affected houses shall be greatly reduced as shown in Table-2 below:

Table-2 Comparison of the Number of Affected Houses

<table>
<tr><th colspan="3" rowspan="3">Section</th><th rowspan="3">Road Width (m)</th><th colspan="3">Number of Affected Houses</th></tr>
<tr><th rowspan="2">Rehabilitation of Existing A3(*1)</th><th colspan="2">DD Route</th></tr>
<tr><th>The Study Team (*1)</th><th>ERA･RAP</th></tr>
<tr><td>Dejen to entrance of D/Markos (*2)</td><td colspan="2">Sta.00+185-60+857</td><td>10.0－19.0</td><td>26</td><td>26</td><td>75</td></tr>
<tr><td rowspan="6">D/Markos Town</td><td rowspan="3">1</td><td>Section-1 Sta.60+857-61+900</td><td>15.0</td><td rowspan="3">10</td><td rowspan="6">86</td><td rowspan="6">84</td></tr>
<tr><td>Section-2 Sta.61+900-64+300</td><td>19.0</td></tr>
<tr><td>Section-3 Sta.64+300-65+000</td><td>21.5</td></tr>
<tr><td rowspan="3">2</td><td>Section-1</td><td>15.0</td><td rowspan="3">6</td></tr>
<tr><td>Section-2</td><td>17.0</td></tr>
<tr><td>Section-3</td><td>19.0</td></tr>
<tr><td colspan="4">Total（Dejen－D/Markos）</td><td>32 - 36 (*3)</td><td>112</td><td>159</td></tr>
</table>

Note) *1: The number of affected houses is based on site survey by the Study Team and/or google map
Rental housings should be included in affected houses because of involuntary relocation.
*2: Section between Dejen to entrance of Debre Markos
*3: The number of affected houses will vary (from 32 to 36) depending on the road section plan.

5. Recommendation

The JICA Study Team recommends that the existing A3 route in Debre Markos should be rehabilitated under the Project for Rehabilitation of Trunk Road, Phase IV taking into account the following;

(1) Environmental aspect

① The number of affected houses of DD Route by HEC (Alt.1) is obviously classified in Category A of the JICA Environmental Guideline.

② The number of affected houses of rehabilitation of existing A3 is less than that of Category A.

③ Effect of heavy vehicles noise and exhaust emissions to residents is reduced in case of rehabilitation of existing A3.

(2) Technical aspect

① The rehabilitation plan of existing A3 (Alt.2) is superior to DD Route by HEC (Alt.1) in all items of technical aspect.

② Transit traffic and local traffic should be separated as much as possible, so it is common practice that the international trunk road should be planned to avoid to passing through the center of populous city.

(3) Recommendation

In the context of above two aspects, the rehabilitation of existing A3 in Debre Markos should be recommended.

(3) Number of Affected Houses in case of Rehabilitation of existing route A3

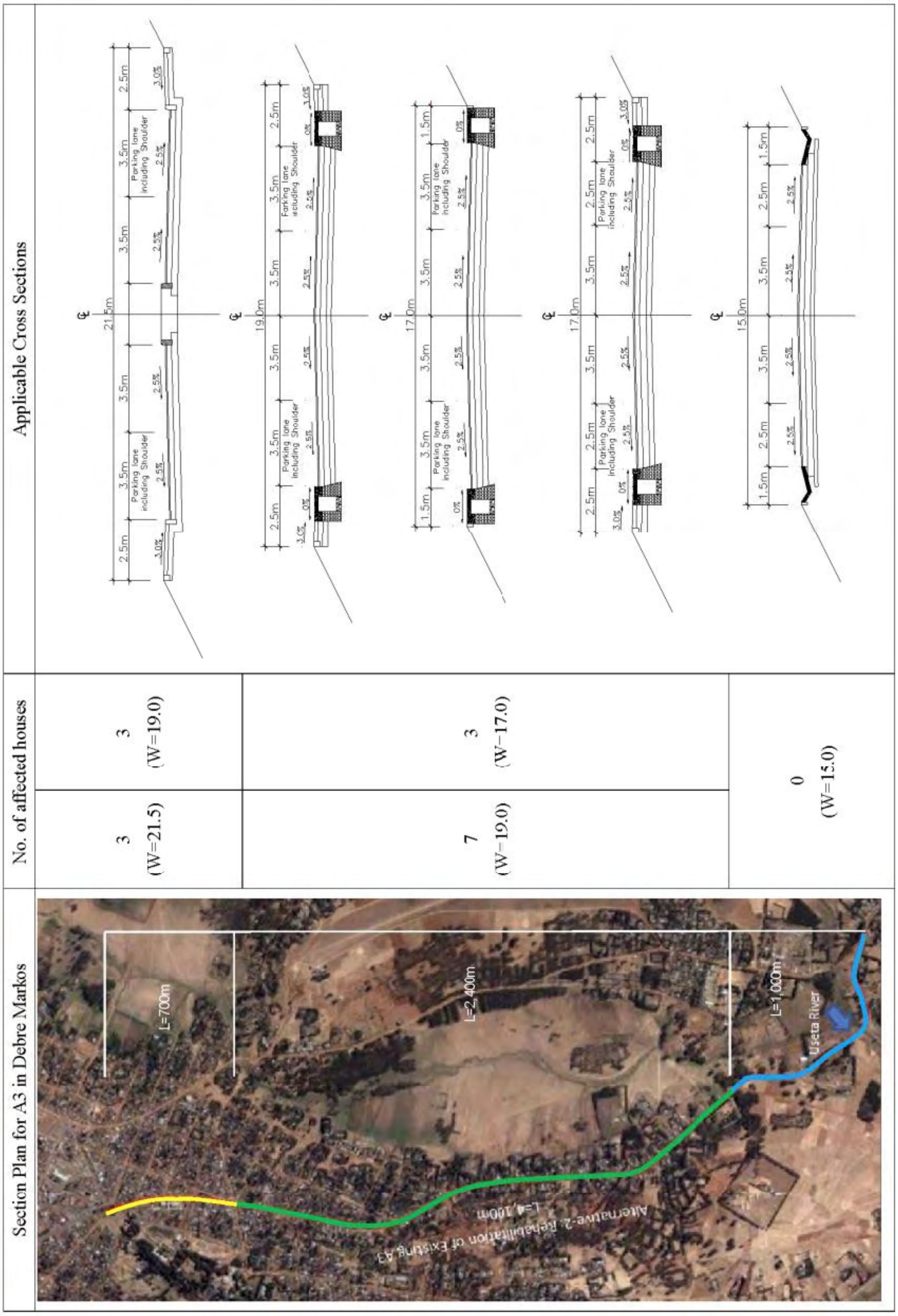


Fig.-4 Section and Cross Section Plan

Annex-1: Detailed Number of Affected Houses (Whole Section)

Section	Town	Affected houses (AH)by ERA・D/D・RAP								Distance between AH and road centerline (m)							Road width	Judge by JICA Team*4
		Mud	Tkul	Block	G+1	G+2	G+3	G+4	計	Mud	Tkul	Block	G+1	G+2	G+3	G+4	—	
Sta.00+185-03+043	Dejen	8							8	12-15							19.0	0
Sta.06+754-09+226	Yitonora	9							9	13-15							12.0	0
Sta.18+552-21+604	Wejel	24							24	12-15							19.0	0
Sta.27+444-30+497	Lumame	9							9	13-14							19.0	5
Sta.30+497-33+198	(Rural)	3							3	11-15							10.0	0
Sta.38+764-41+216	Godelma	1							1	15							12.0	0
Sta.45+400-47+500	Amber*1	ND							ND	ND							19.0	14
Sta.50+186-52+669	(Rural)*2		1						1								10.0	4
Sta.57+700-57+900	Chemoga	11							11	10-13							12.0	0
Sta.58+090-60+857	(Rural)*3	9							9	1-10							10.0	3
Subtotal（From Dejen to D/Markos entrance）									75	Subtotal by JICA's proposal								26
Sta.60+857-63+613	D/Markos	31		6	2	6	2	3	50	5-15		10-15	7-10	10	10	11	21.5	30
Sta.63+613-64+889	(DD Route)	28		2	2	2			34	2-18		10	10-11	10				56
Total by ERA's design									159	Total by JICA's proposal								112
Sta.60+857-61+900	D/Markos																15.0	0
Sta. 61+900-64+300*5	(Ex. A3)	2		5					7	9-15		10-15					19.0	7
																	17.0	3
Sta.64+300-65+000		3							3	9-10							21.5	3
																	19.0	3
Total in case of using existing road in D/Markos (Dejen−D/Markos)																		32-36*6

Note: *1 No data on ERA・RAP.
*2 Realignment sections in Yeda
*3 Short cut for realignment
*4 Satellite photograph besides field survey is used.
*5 4m-strips outside the road width are assumed affected during construction stage.
*6 Depend on road width in the D/Markos city, the number of a ffected houses varies from 32 to 36.

Ref. No.ERA/ADM/101022/PO

22/10/2010 Date: 22 October 2010

Ms Hiwot Mossisa
Central Region Directorate, Acting Director
Ethiopian Roads Authority (ERA)
Addis Ababa

Dear Madam,

RE: ROAD/STRUCTURE DESIGN CONDITION, ROAD ALIGNMENT, CROSS SECTIONS AND COUNTERMEASURE FOR BLACK COTTON SOILS ON THE PROJECT FOR REHABILITATION OF TRUNK ROAD, PHASE IV

We would like to draw your attention to the aforementioned project and previous meetings we have held, the latest one being on 19th of October, 2010 in your office at Alemgena on the subject matter referenced above.

In a series of previous meetings which consisted of discussion on the matter of road realignment in Debre Markos town, we have explained to your institution the inappropriateness of the realignment proposed by the HEC in their detail design. To support our argument/proposal in favor of taking the existing route A3 alignment, we have submitted in the meeting a document titled "*Study for Route Selection in Debre Markos under the Project for Rehabilitation of Trunk Road, Phase IV*" dated 28th September 2010. It has since been agreed that we proceed with our study and design following the existing route A3 in Debre Markos town.

Regarding the latest meeting held with yourselves on 19th October 2010 regarding applicable design standard, typical cross sections of road, countermeasure for expansive soil (black cotton soil) and bridge planning (bridges and culverts) including cross sections, we discussed matters based on the guiding document distributed in the meeting titled "*Discussion for the Design Conditions and Concepts*". In the course of the meeting most matters in the above documents were agreed upon except few that were left pending for further reconsideration or after the conclusion of topographic survey. Of the pending matters, we would like to mention them one by one and state our envisaged action plan

Pending Item	Planned action
1. Min. gradient (from 0.5% to 0.3%	The team will prepare an explanation covering such matters as drainage, cross gradient, pavement design for skid resistance in wet conditions etc, and explain to ERA
2. Km 58~58.7 alignment to follow existing A3 route	The Team to complete topographic survey to assess and confirm elements such as number of PAPs and alignment geometry before settling for the proposed alignment.
3. Km 61.3~62.4 Road width	The Team to re-check the possibility of increasing the shoulder width from 2.5m to 3.5m depending on the availability of free space without increase in number of affected houses and PAPs
4. Km 64.2~65.4 Median width	Median size of 0.5m is acceptable in principle but the team will reconsider widening the median according to the results of topographic survey and if the number of affected houses and PAPs does not increase.
5. Black Cotton Soil treatment	The Team will revise the plan for countermeasure including but not limited to; benching into existing pavement for proper interlocking between exiting pavement layers and widened section and to minimize/eliminate differential settlement, increasing the replacement depth, installing sub-drains, etc .

13 page.

12-1, Honmachi 3-chome, Shibuya-ku, Tokyo, 151-0071 Japan
Tel. +81-3-6311-7894 Fax. +81-3-6311-8043 Cell: 0912 964 852 E-mail. tatsumi@oriconsul.com

Regarding plan for detour during bridge or road construction, the Team will consider case by case depending on season of construction and site condition, where to apply soil embankment detour, temporary culvert and embankment detour, Bailey bridge detour, graded and gravel-leveled detour road, etc, in the project construction plan. However, the final plan will be subject to modifications arising from e.g. the Contractor's proposal and so on.

This is for your kind information, update concerning pending design issues for your action and/or the Team's action where applicable.

Attached hereto please find documents with the following titles:

1) Study for Route Selection in Debre Markos under the Project for Rehabilitation of Trunk Road, Phase IV
2) Discussion for the Design Conditions and Concepts

Yours sincerely,

Oriental Consultants Co. Ltd. * The Project for Rehabilitation of Trunk Road, * Ethiopia

Masaaki TATSUMI Dr. Eng
Oriental Consultants Company Limited
JICA Study Team, Chief Consultant

Cc: Mr. Abdo Mohammed,
DDG Engineering & Regulatory Department,
Ethiopian Roads Authority.

22/10/10

12-1, Honmachi 3-chome, Shibuya-ku, Tokyo, 151-0071 Japan
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Agenda for the meeting
for the Preparatory Survey on the Project for Rehabilitation of Trunk Road,
Phase IV
in the Federal Democratic Republic of Ethiopia

Venue: ERA Central Regional Directorate Office, Alemgena

Time: 2010/10/19, 14:30 – 16:00

Agenda:The meeting will discuss matters related to the abovementioned project with particular attention to the following items;

1. Applicable Design Standard
2. Typical Cross Sections of Road
3. Countermeasure for the Expansive soil (Black Cotton soil)
4. Bridge Planning (Bridges and culverts) including cross sections

Meeting Material Content

(1) Table of Geometric Design Conditions
(2) Figure of Typical Cross Section of Road
(3) Figure of Countermeasure for the BC soil
(4) Table of Subgrade Condition in the Project Road
(5) Table of Concept of Structures (Bridges and Culverts)

Discussion for the Design Conditions and Concepts

1. Applicable Design Standard

(1) Design Standards

The application of proper design standards will ensure road safety, high standard service level and comfort for road users through the provision of adequate sight distance and roadway space.

The design and construction standards for new roads and bridges have been established by ERA in Ethiopia. The following is the composition of ERA's Road Design Manual:

- Geometric Design Manual
- Drainage Design Manual
- Pavement Design Manual Vol.1: Flexible Pavements and Gravel Roads
- Pavement Design Manual Vol.2: Rigid Pavements
- Pavement Rehabilitation and Asphalt Overlay Manual
- Bridge Design Manual
- Site Investigation Manual
- Standard Detail Drawings
- Standard Technical Specifications

The latest version of the manual was published in 2002.

The Road Design Manual is intended for use in the design of all federal roads in Ethiopia. The purpose of the manual is to give guidance and recommendations to the engineers responsible for the design of federal roads.

(2) Geometric Design Parameters

Geometric design standard was prepared as part of the Road Design Manual in Ethiopia. This design standard will be basically followed for this study as well as HEC's design. In case essential parameters are not expressly stipulated in design standard, the Study Team will refer to other design standards and manuals (such as SATCC and Japanese Road Geometric Standard).

Observations during the field survey indicate that the Road under Study traverses various topographical conditions. Thus, the Study Team finally recommends following geometric standard based on the design standard and HEC's design.

Road Class (DS3: Paved)							
Design Element	Unit	Flat	Rolling	Mountainous	Escapment	Urban/Peri-Urb	Remarks
Design Speed	km/h	100	85	70	60	50	
Min. Stopping Sight Distance	m	205	155	110	85	55	
Min. Passing Sight Distance	m	375	340	275	225	175	
% Passing Opportunity	%	50	33	25	0	20	
Min. Horizontal Curve Radius	m	395	270	175	125	85	
Min. Length of Curve	m	300	300	300	300	300	Tangent Angle of 5° or less (ERA Standard)
	m	350	260	190	150	100	Japanese Standard: Design Speed x 6sec.
Transition Curves Required	-	Yes	Yes	No	No	No	
Max. Radius for use of a Transition Curve	m	1450	1050	-	-	-	SATCC: 0.145 x V^2
Spiral Length	m	R=400:L=123, R=500:L=98, R=600:L=82, R=700:L=70, R=800:L=62, R=900:L=55, R=1,000:L=49, R=1,100:L=45, R=1,200:L=41, R=1,300:L=38, R=1,400:L=35	R=300:L=100, R=400:L=75, R=500:L=60, R=600:L=50, R=700:L=43, R=800:L=38, R=900:L=34, R=1,000:L=30	-	-	-	SATCC: $0.0702V^3/(RC)$ C: Rate of increase in centripetal acceleration (m/s3); 1<C<3 (1.438 is recommended.)
Max. Gradient (desirable)	%	3.0	4.0	6.0	5.0	6.0	
Max. Gradient (absolute)	%	5.0	6.0	8.0	8.0	8.0	
Min. Gradient (desirable)	%	0.5	0.5	0.5	0.5	0.5	
Min. Gradient (absolute)	%	0.3	0.3	0.3	0.3	0.3	Japanese Standard: Design Speed x 6sec.
Crest Vertical Curve (k-value)	k	105	60	31	18	12	
Sag Vertical Curve (k-value)	k	51	36	25	18	12	
Max. Superelevation (e)	%	8.0	8.0	8.0	8.0	4.0	
Normal Crossfall	%	2.5	2.5	2.5	2.5	2.5	
Shoulder Crossfall	%	4.0	4.0	4.0	4.0	4.0	
Right of Way	m	COI	COI	COI	COI	COI	Corridor of Impact (Construction Limit)

***Normal Wereda towns and Kebele towns are included in Urban/Pre-Urban.**

Major changes and additions are as follows:

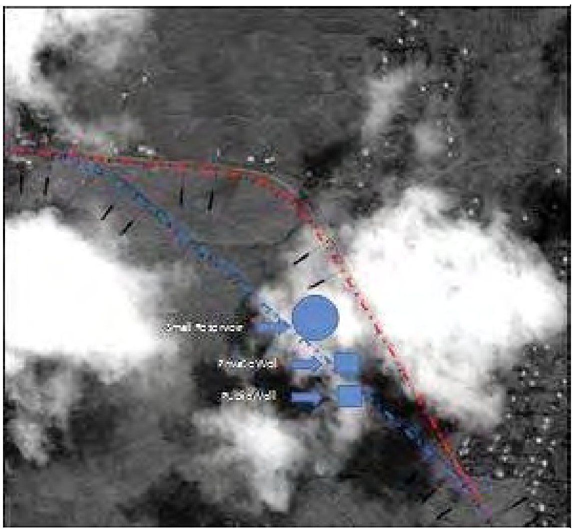
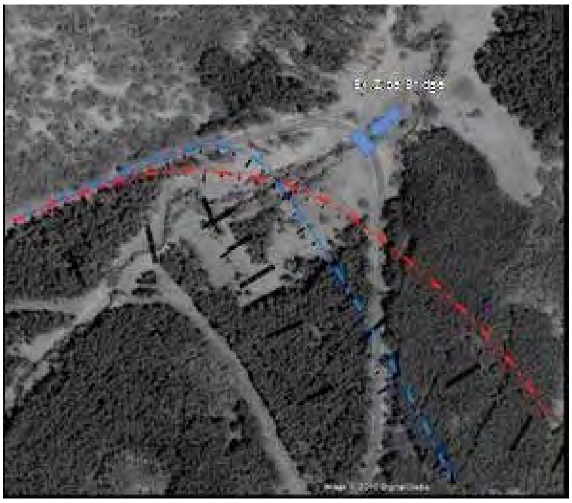
- Min. Length of Curve: Regardless of design speed, ERA's standard stipulates length of 300m. However, it is difficult to secure the curve length of 300m in hilly, mountainous and densely populated areas. It is for this reason that the Study Team will recommend the use of Japanese Standard that considers the curve length depending on the design speed.

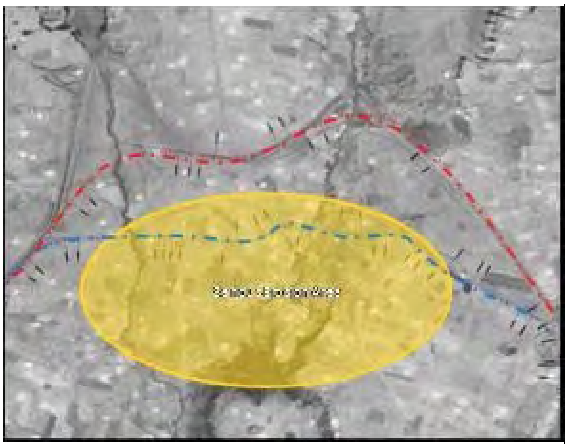
- Max. Radius for use of a Transition Curve: not stipulated (Use of SATTC)

- Spiral Length: not stipulated (Use of SATTC)

- Min. Gradient: ERA's standard stipulates minimum gradient of 0.5%. However, securing of min. 0.5% in flat area such as Yeda would mean a substantial increase in construction cost with the commensurate increase in affected area. Thus min. gradient of 0.3% on Japanese standard will be used in absolute necessity.

(3) Major Alignment Change

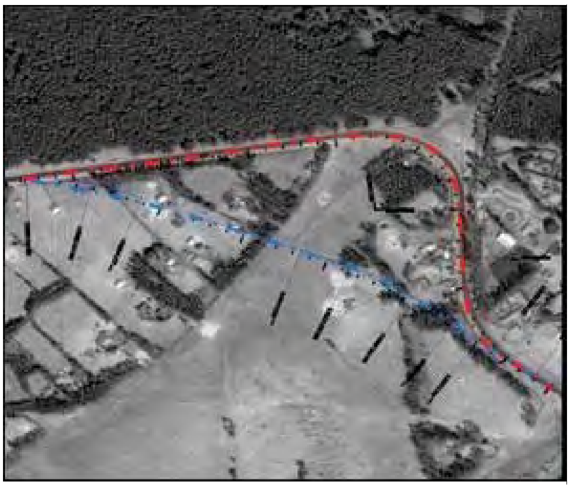
Location Map	Reasons & Interferences
	7.4km – 8.7km: Yetnora Reason - To avoid the following interferences - To reduce the number of affected houses - Possible to improve horizontal alignment by new CL Interference - Two wells - Small reservoir - Some houses (blue line) : Original CL by HEC (red line) : Proposed new CL
	44.0km: Ziba Br. Reason - To improve the alignment for traffic safety (response to high speed) Interference: - (blue line) : Original CL by HEC (red line) : Proposed new CL
	46.2 – 46.7km: Amber Reason - To avoid the following interferences - To reduce the number of affected houses - Possible to improve horizontal alignment by new CL Interference - Public water supply facility - Some houses (blue line) : Original CL by HEC (red line) : Proposed new CL



52.1 – 55.2km: Erosion prone Area
Reason
- To avoid the serious erosion area and high embankment
- Possible to improve horizontal alignment by new CL

Interference: -

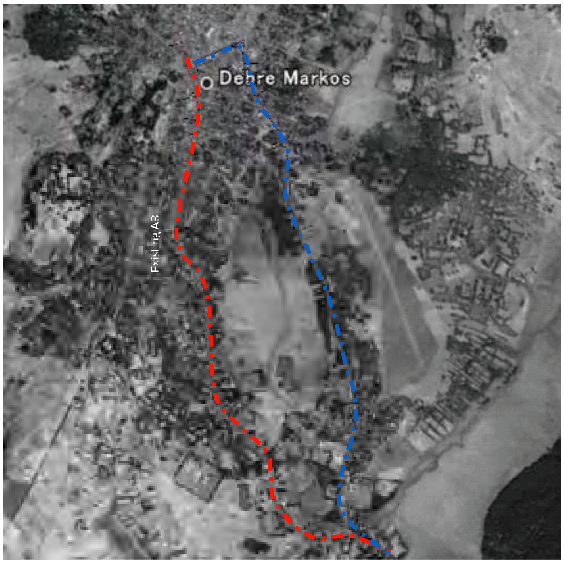
: Original CL by HEC
: Proposed new CL



58.0 – 58.7km: Chemoga
Reason
- To reduce the number of affected houses
- Possible to improve horizontal alignment

Interference
- Some houses

: Original CL by HEC
: Proposed new CL



61.3km – End: Debre Markos
Reason
- Adequacy of international trunk road
- Complicated connection to A3 (Original route)
- To reduce the number of affected houses

Interference
- Some houses and buildings

: Original CL by HEC
: Proposed new CL

(4) Pavement Design

- ✓ Pavement Design Condition: It is based on the HEC's design
- ✓ Design Life: 15years
- ✓ Sub-grade Strength Class: S2 (0km – 53km), S3 (53km – 65km)
- ✓ Vehicle Equivalent Factor (VEF): see table below:

Vehicle Category	Base year Traffic	T_c	EF	CESA
Large Bus	72	675853.48	2.29	1547704.47
Medium Truck	45	403331.17	2.76	1113194.03
Heavy Truck	36	322664.93	7.25	2339320.78
Truck and Trailer	46	412294.08	12.26	5054725.42
			Total	10,054,944.70
Applying lane distribution factor of 90% for single lane i.e. .9*10054944.7				9,049,450.23 (Class T6)

Based on ERA's manuals, for traffic classes of T6, the required pavement layers with asphalt concrete surfacing, crushed granular road base and granular sub-base for the design periods of 15 years are as shown in the table below.

Station	Sub-grade class	Pavement Layers (mm) for 15 years & traffic class T6			
		AC	Base course	Sub- base	G.C
0km-53km	S2	100	200	225	200
53km-65km	S3	100	200	250	-

Detail design report by HEC had finally recommended the following pavement layers because uncertainties such as the traffic volume and analysis as well as the sub grade soil testing and evaluation should be considered.

Station	Sub-grade class	Traffic class	Pavement Layers (mm) for 15 years & traffic class T6			
			AC	Base course	Sub- base	G.C
0km-53km	S2	T6	100	200	225	200
53km-65km	S3	T6	100	250	300	-

However, for Japanese ODA policy, minimum requirement based on technical theory is acceptable. Thus the Study Team will recommend the following pavement layers:

Station	Sub-grade class	Traffic class	Pavement Layers (mm) for 15 years & traffic class T6			
			AC	Base course	Sub- base	G.C
0km-53km	S2	T6	100	200	250*	200
53km-65km	S3	T6	100	200	250	-

*225mm of sub-base required by the manual will be changed to 250mm in consideration of easy construction and supervision.

2. Typical Cross Sections

(1) Recommendable Typical Cross Sections

The Study Team will recommend the following typical cross sections based on the field survey and design review. Main changes are as follows:

- ✓ Reduction of median strip: 2.5m to 0.5m
- ✓ Installation of unpaved protection shoulder: 0.5m

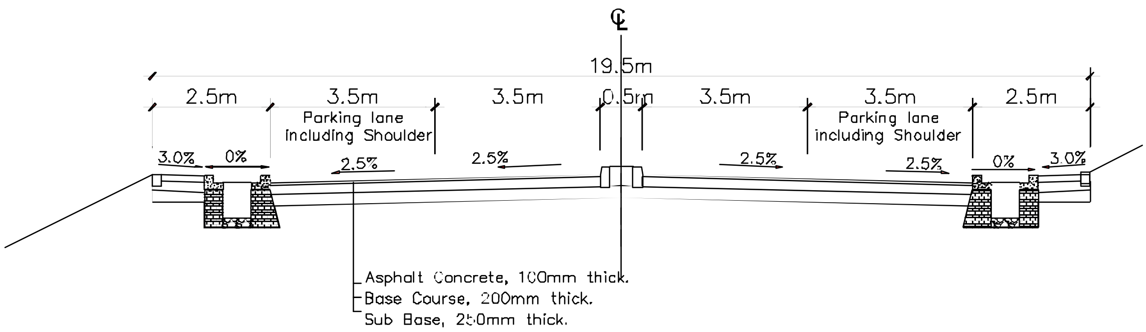


Figure-1 Proposed Typical Cross Section (D/Markos Town Center Section)

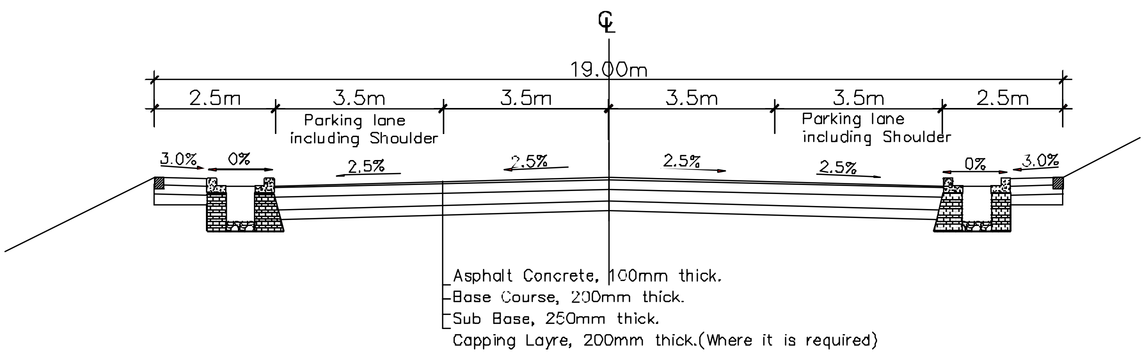


Figure-2 Proposed Typical Cross Section (Wereda Town and Populated Area in D/Markos)

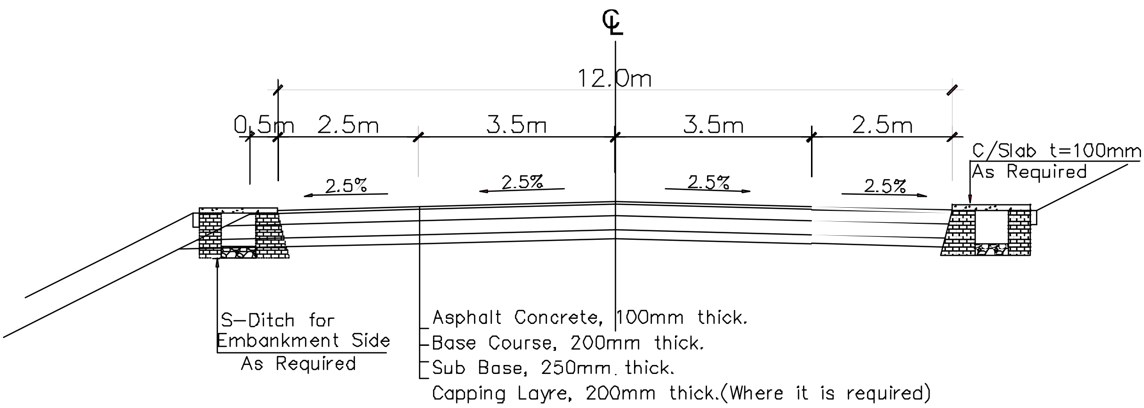


Figure-3 Proposed Typical Cross Section (Kebele Town & Entrance of D/M & End of Dejen)

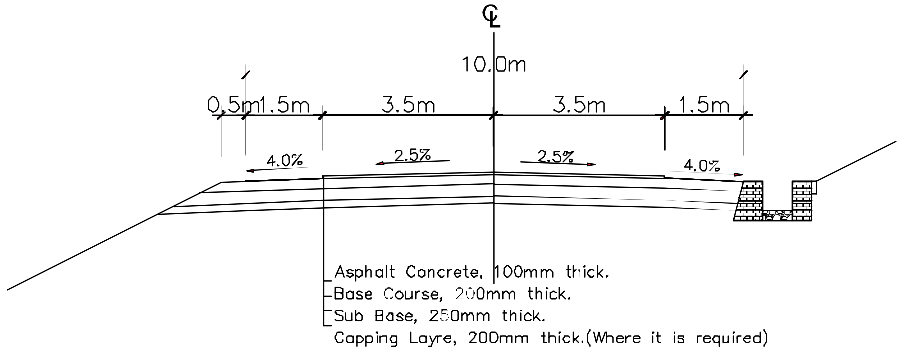
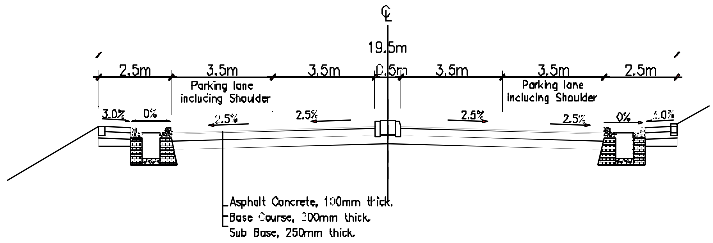
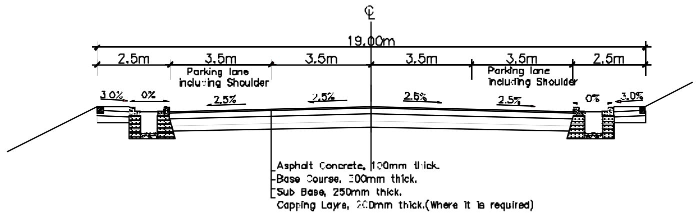
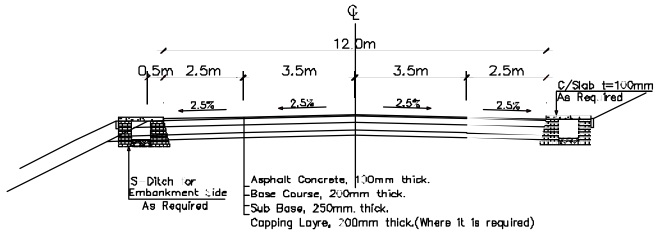


Figure-4 Proposed Typical Cross Section (Rural Section)

(2) Typical Cross Section in Debre Markos Town

Section Plan for A3 in Debre Markos	Applicable Cross Sections
	64.2km – 65.4km (End)  62.4km – 64.2km  61.3km – 62.4km 

3. Countermeasures for the BC Soil (Expansive Soil):e.g. Rural Area

Black cotton soils are problematic for Civil Engineers, because of their unconventional behavior. These soils show large volumetric changes with respect to seasonal variation of moisture content. These soils when subjected to vehicular traffic, road pavement heaves and cracks due to cycles of swelling and shrinkage. The Study Team will recommend the following measures based on the field survey, soil testing and visits made to similar projects.

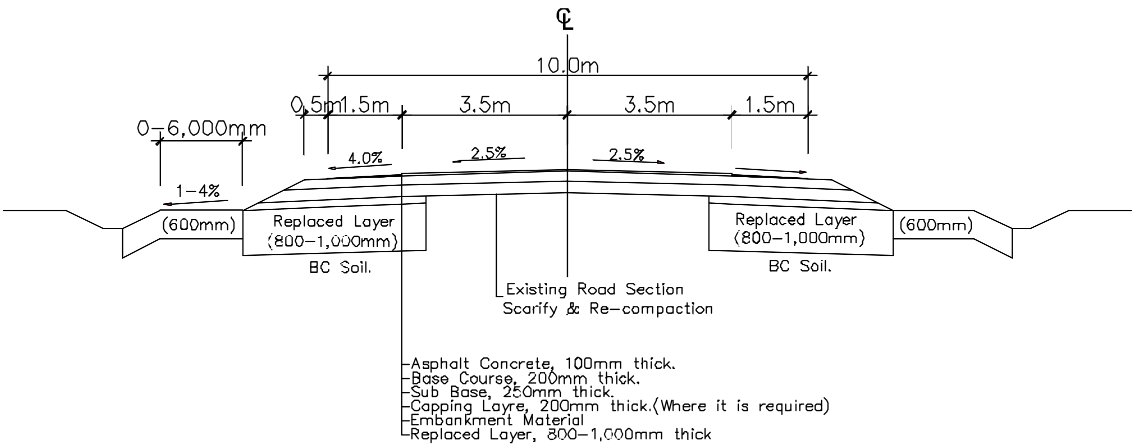


Figure-1 Existing Pavement Section in Rural Area

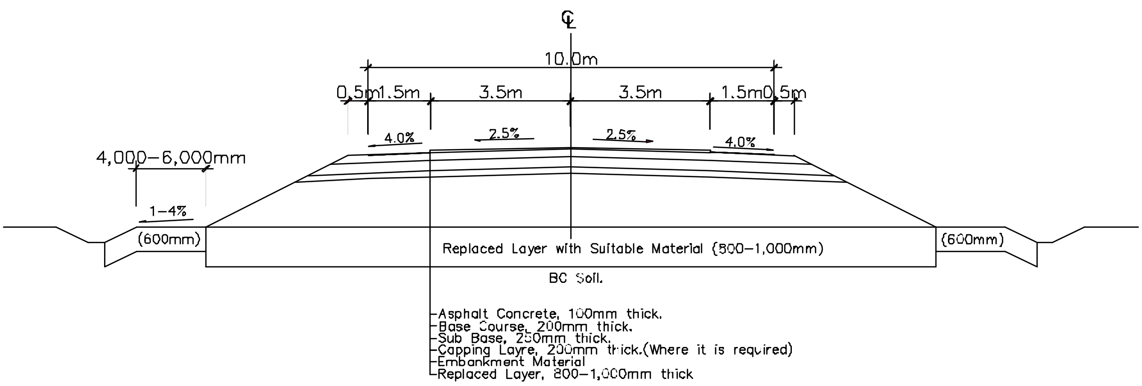


Figure-2 New Road Section (Bypass) in Rural Area

Subgrade condition between Dejen and Lumame

Boring or Pit	Chainage	Location	BCS	Red. / Brn	N value	CBR	Swell %	PI	NMC	S.L.	Eex
NTP 01	1+500		0.8-2.0		< 10			38			
NTP 02	4+000		0.6-2.6		< 10	2	10.0	51			112
NBH 01	5+060		1.0-2.5		8-9			77	39	3.2	
NTP 03	5+500		0.5-1.9		< 10			48			
BH 09	8+500	Yetnora	0.95-2.7		2-6			47			
NTP 05	9+500		0.8-2.8		< 10			46			
BH 10	10+500		0.0-2.0		3-10			36	31		
BH 11	11+400		0.0-4.0		4-9			25	40		
NTP 06	11+500		0.5-3.1		< 10			73			
BH 12	12+500	Bechet	0.5-2.5		1-6			52	46		
NTP 07	13+500		0.7-2.5		< 10	2	8.0	42			97
NBH 02	14+560		0.6-2.0		8			72	39	2.8	
NTP 08	15+500		0.8-2.5		< 10			62			
NTP 09	16+500		0.9-2.6		< 10			73			
NTP 10	17+500		0.6-2.4		< 10			74			
BH 13	18+500	Taba	0.0-3.0		1-4			78	51		
NTP 11	19+500	Wejel	0.5-2.4		< 10			47			
BH 14	20+000	Aba Adem	0.0-2.1		3-4			52			
NBH 03	20+090	Aba Adem	0.5-3.5		9-14			70	44	4,4	
NTP 12	21+500		1.1-2.4		< 10			51			
NBH 04	22+040	Abeya	1.0-13.0		2-9			51	46	7.3	
NBH 05	22+080	Abeya	1.0-11.0		4-11			53	44		
NTP 13	23+000		0.6-3.0		< 10	2	8.4	51			128
NTP 14	24+000		1.6-2.5		< 10			57			
NTP 15	26+500		0.8-3.0		< 10	2	12.4	43	53	9	90
NBH 06	26+500		0.6-2.5		4-5			52	53	6.2	
NTP 16	27+500		0.7-2.7		< 10			71			
NTP 17	29+000		0.5-3.0		< 10			63			
NBH 07	29+300	Bogena	0.6-3.9		10			43	31		
NBH 08	29+390	Bogena	1.0-3.9		5-6			70	61		
NPT 18	30+000		1.1-3.0		< 10			59			

Note; BCS: Black cotton soil, Eex: Expansiveness

Subgrade condition between Lumame and Debre Markos

Boring or Pit	Chainage	Location	BCS	Red. / Brn	N value	CBR	Swell %	PI	NMC	S.L.	Eex
NTP 19	32+000		-	Red		9	1	43	35	14	81
NTP 20	34+500		-	Brn				46			
NBH 09	35+670	Getla									
NTP 21	36+000		0.0-1.3		< 10			50			
NTP 22	37+500		0.0-1.4		< 10			54			
NTP 23	38+500		0.5-2.7		< 10			32			
NTP 24	40+500		-	Red				28			
NTP 25	42+500		-	Red		9	1.2	28	31	17	33
NTP 26	43+500		-	Red				25			
NBH 10	44+060		-	Red	> 12			21	35	15	
NTP 27	45+500		-	L/Brn				24			
NTP 28	46+500		-	D/Brn				40			
NBH 11	47+420	Yeda	0.0-5.5		4-10			57	35	6.8	
NTP 29	48+000	Yeda	> 4.0		< 10			58			
NBH 12	48+900	Yeda	0.0-10		5-10			40	43	7.8	
NBH 13	49+200	Yeda	0.0-10		1-9			32	49	10.7	
NTP 30	49+500	Yeda	> 4.0		< 10	2	7.9	43	36	14	81
NBH 13-2	50+200	Yeda	0.0-2.4		4-10			54	37	2.5	
NTP 31	50+500	Yeda	0.0-2.7		< 10			44	46	13	85
NTP 32	51+500		-	Red				37			
NTP 33	53+000		-	L/Brn				22			
NBH 15	53+500	Ambesh	-	D/Brn							
NTP 34	55+000		-	Red				38			
NTP 35	56+500		-	D/Brn		4	3.8	31	41	14	49
NTP 36	57+500		-	Red				39			
NBH 16	57+890	Chemoga	-	L/Brn	2-8			31	45		
NBH 17	58+020	Chemoga	-	L/Brn	> 11			40	35		
NTP 37	59+000		-	Red				36			
NTP 38	60+500		-	Red				23			
BH 19	61+000	Wiseta	-	Red	2			27	44		

Note; Red; Reddish silty clay, L/Brn; Light brown silty clay, D/Brn; Dark brown silty clay

4. BRIDGE PLANNING

(1) Use of Existing Bridges

Existing bridges will be used if they meet the criteria for compatibility to the new road alignment, structural soundness, and functional requirements. The Bridge Design manual of ERA requires the minimum carriageway of 7.0 m for 2-lane bridges. If necessary and if feasible, repair works will be conducted to improve the function and to satisfy the requirements.

(2) Bridge Length

Based on the necessary clearance under the superstructure such as waterway function and topography, the bridge length will be decided.

(3) Carriageway

Carriageway will be decided according to the Bridge Design Manual of ERA, in consideration of the continuity with approach roads and expected number of pedestrians. The carriageway width of bridges in rural area is 8.0m, (0.5m+3.5m+3.5 m+0.5m). The Aba Adem Bridge which is located in Wejel and the Useta Bridge in Debre Markos are expected to be used by many pedestrians. The carriageway of the Aba Adem Bridge and the Useta Bridge is 10m, (1.5m+3.5m+3.5m+1.5m), and 12m, (2.5m+3.5m+3.5m+2.5m), respectively taking into account the traffic conditions.

(4) Bridge Type

- ✓ Type by Material

The Reinforced Concrete Bridge (RC Bridge) is the most suitable bridge type for short spans. Table-1 shows the comparison of bridge types by materials.

Type		Features	Evaluation
Concrete Bridge	Reinforced Concrete Bridge	Suitable for short spans No major technical difficulties No difficulty in obtaining necessary materials No difficulty in Quality Control Cost-effective Suitable for Technology Transfer	○
	Prestressed Concrete Bridge	Suitable for longer spans than RC bridges Light weight than RC bridges Advance technology Need of imported materials Difficulty in Quality Control Costly than RC bridges	×
Steel Bridge		Imported materials Difficulty in construction Costly than concrete bridges Difficulty at maintenance stage Easy to repair than concrete bridges	×

✓ Structural Type

Structural Type will be decided by the following criteria.

Structural Type	Span Range
Reinforced Concrete Slab Bridge	5～10m
Reinforced Concrete Girder Bridge	10～20m

✓ RC Box Culvert

When the bridge construction is judged to be difficult or not appropriate due to difficult site conditions, the RC Box Culvert will be planned. The following table compares the bridges and RC box culverts.

Structure	Features
Bridges	Suitable for longer spans Wider clearance under the superstructure Concentration of forces at abutments and piers Need of strong ground layer Need of bearing supports and expansion joints
RC Box Culverts	Smaller clearance than that of bridges No bearing supports and expansion joints No need of abutments and piers Applicable to less strong ground condition No difficulty in adjustment of road surface

(5) Design Method

The bridge design shall meet the Bridge Design Manual of ERA. However, calculation is based on Japanese bridge design methods and check if the result meets the Bridge Design Manual of ERA.

✓ Bridge Planning

a) Existing Bridges

Bridge	Length	Carriageway	Type	Major Repair
Asamatech	5.0 m	7.0 m	RC Girder	Slab, Parapet
Taba	13+13 m	7.3 m	RC Girder	None
Bogena	13.1 m	7.0 m	RC Girder	Slab, Parapet
Chemoga	67.0 m	7.0 m	Masonry Arch	Slab, Parapet

b) New Bridges

Bridge	Length	Carriageway	Type	Substructure Type
Bechet	17+17 m	8.0 m	RC Girder	Direct Foundation
Abadem	15 m	10.0 m	RC Girder	Direct Foundation
Abeya	3@4.5 m	8.0 m	RC Culvert	—
A3-4-012	2@4.5 m	8.0 m	RC Culvert	—
Getla	15+15 m	8.0 m	RC Girder	Direct Foundation

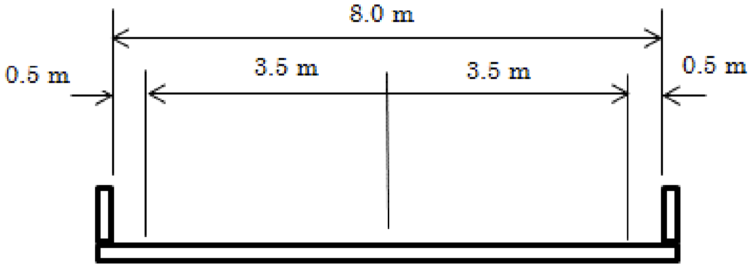
A3-4-017	15 m	8.0 m	RC Girder	Direct Foundation
Zeba	15 m	8.0 m	RC Girder	Direct Foundation
Yeda-A	2@ 4.5 m	8.0 m	RC Culvert	—
Yeda-B	2@ 4.5 m	8.0 m	RC Culvert	—
Yeda-C	5@ 4.5 m	8.0 m	RC Culvert	—
Ambesh	2@ 4.5 m	8.0 m	RC Culvert	—
Useta	10+10 m	12.0 m	RC Girder	Direct Foundation

c) Existing and New Bridges (reference)

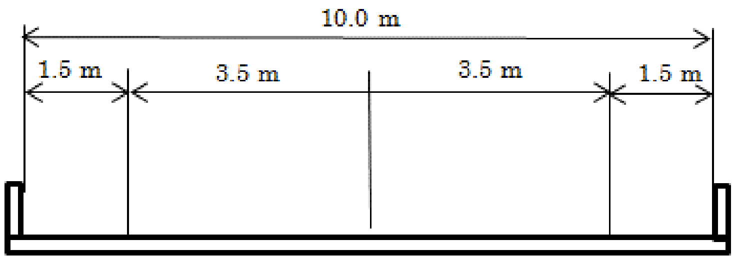
Bridge	Existing Bridge			New Bridge		
	Length	Carriageway	Type	Length	Carriageway	Type
Asamatech	5.0 m	7.0 m	RC Girder			
Bechet	32.0 m	6.0 m	Masonry Arch	17+17 m	8.0 m	RC Girder
Taba	13+13 m	7.3 m	RC Girder			
Abadem	12.0 m	6.0 m	Masonry Arch	15m	10.0 m	RC Girder
Abeya	7+7+7 m	6.0 m	RC Girder	3@ 4.5 m	8.0 m	RC Culvert
Bogena	13.1 m	7.0 m	RC Girder			
A3-4-012	7.8 m	5.5 m	Masonry Arch	2@ 4.5 m	8.0 m	RC Culvert
Getla	13.1 m	7.0 m	RC Girder	15+15 m	8.0 m	RC Girder
A3-4-017	7.0 m	6.0 m	Masonry Arch	15 m	8.0 m	RC Girder
Zeba	11.0 m	5.5 m	RC Girder	15 m	8.0 m	RC Girder
Yeda-1	4@ 5.0 m	7.0 m	RC Girder	2@ 4.5 m	8.0 m	RC Culvert
Yeda-2	4@ 5.0 m	7.0 m	RC Girder	2@ 4.5 m	8.0 m	RC Culvert
Yeda-3	6+6+6 m	7.0 m	RC Girder			
Yeda-4	3.5+4 m	7.0 m	RC Girder	5@ 4.5 m	8.0 m	RC Culvert
Ambesh	8.0 m	6.0 m	Masonry Arch	2@ 4.5 m	8.0 m	RC Culvert
Chemoga	67.0 m	7.0 m	Masonry Arch			
Useta	12.3 m	5.0 m	RC Girder	10+10 m	12.0 m	RC Girder

d) Carriageway Plan (reference)

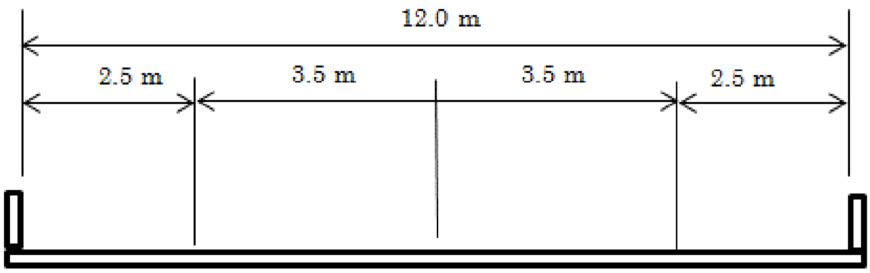
Rural Area



Aba Adem Br (Wejel)



Useta Br (Debre Markos)



Ref. No.ERA/ADM/101025/PO

Date: 25 October 2010

Ms Hiwot Mossisa
Central Region Directorate, Acting Director 25/10/2010
Ethiopian Roads Authority (ERA)
Addis Ababa

Dear Madam,

RE: PROPOSED COUNTERMEASURE FOR EXPANSIVE (BLACK COTTON) SOILS AND PROPOSED MINIMUM VERTICAL GRADIENT ON THE PROJECT FOR REHABILITATION OF TRUNK ROAD, PHASE IV

We would like to draw your attention to the aforementioned project and previous meetings we have held, the latest one being on 22nd of October, 2010 in your office at Alemgena on the subject matter referenced above. It was also agreed that bridge design will be based on ERA's Bridge Design Manual 2002 except that the design procedure will follow Japanese Standard, then the results will be rechecked whether or not they satisfy ERA Standards.

Regarding countermeasure for expansive (black cotton) soils, our proposal was agreed by your side but only in principle with some comments. Your comments were that the Consultant should incorporate a filter membrane (such as geo-textile sheet) and an impermeable membrane on the outer and inner face of the buried gabion, respectively. The inclusion of such membranes and protection method for gabion bed will be decided at a later stage after confirming matters such as highest ground water table, etc, and determining whether or not buried gabions will be applied. At the moment, the concept is to have the image of the probable features of road cross section in town areas. Moreover, your side recommended that a provision for side drains be indicated on the typical cross sections on the existing road section in high embankment and new road section in rural areas.

In response to your comments, we have duly modified our proposal for typical cross sections to be adopted in cases where black cotton soils are predominant. Please see the attached document titled "Countermeasure for expansive soil on the Trunk Road A3 between Dejen and Debre Markos"

Regarding the issue of minimum vertical gradient, we wish to clarify and reiterate our proposal to adopt the 0.3% min gradient as a deviation from the ERA Standard that states 0.5% min gradient as the usual norm. Your attention is drawn to *page 9.9, section 9.7 Minimum Gradients* of ERA Geometric Design Standard that states: "The minimum gradient for the usual case is 0.5 percent. However, flat and level gradients on uncurbed paved highways are acceptable when the cross slope and carriageway elevation above the surrounding ground is adequate to drain the surface laterally."

It is in the strength and spirit of the above extract from ERA manual that we would like to request for a departure from the ERA's usual-case standard in line with Chapter 2, Section 2.3 page 2-1 of ERA Manual 2002 that stipulates the information required to be submitted to ERA for approval of the requested departure from standard.

For details please refer to the attached document titled "Acceptable Minimum Gradient (Acceptable Geometric Parameter)" Moreover, please see our departure request as summarized in the table below;

12-1, Honmachi 3-chome, Shibuya-ku, Tokyo, 151-0071 Japan
Tel. +81-3-6311-7894 Fax. +81-3-6311-8043 Cell: 0912 964 852 E-mail. tatsumi@oriconsul.com

Road Name	Facet of Design	Usual Standard	Proposed departure	Reasons for Departure
Trunk Road A3, between Dejen and Debre Markos (Flat lowlands such as Yeda area)	Minimum (longitudinal) Gradient	Min 0.5%	Min 0.3%	- To reduce the volume of earthworks thereby reducing construction cost. - To reduce affected area.

Some of the mitigation measures we propose with the use of min 0.3% gradient are;

i) Use of high-type AC pavement: 10cm (double layer)
ii) Accurately set cross slope of 2.5% to ease lateral surface draining
iii) Use of high standard quality control to achieve improved firm sub-grade

We therefore request for your evaluation and approval of our proposals made in this letter for the expeditious progress of the design work.

Yours sincerely,

ORIENTAL CONSULTANTS Co. Ltd. The Project for Rehabilitation of Trunk Road, ETHIOPIA

Masaaki TATSUMI Dr. Eng
Oriental Consultants Company Limited
JICA Study Team, Chief Consultant

Cc: Mr. Abdo Mohammed, Sut 25\10\10
DDG Engineering & Regulatory Department,
Ethiopian Roads Authority.

1. Acceptable Minimum Gradient (Acceptable Geometric Parameter)

As discussed in the previous meetings held on 19th and 22nd of October, 2010, the JICA Study Team recommended using 0.3% as min. gradient as follows:

- Min. Gradient: ERA's standard stipulates minimum gradient of 0.5%. However, securing of min. 0.5% in flat area such as Yeda would mean a substantial increase in construction cost with the commensurate increment of affected area. Thus min. gradient of 0.3% according to Japanese standard will be used in absolute necessity.

Road Class (DS3: Paved)

Design Element	Unit	Flat	Rolling	Mountainous	Escarpment	Urban/Peri-Urb	Remarks
Design Speed	km/h	100	85	70	60	50	
Min. Stopping Sight Distance	m	205	155	110	85	55	
Min. Passing Sight Distance	m	375	340	275	225	175	
% Passing Opportunity	%	50	33	25	0	20	
Min. Horizontal Curve Radius	m	395	270	175	125	85	
Min. Length of Curve	m	300	300	300	300	300	Tangent Angle of 5° or less (ERA Standard)
	m	350	260	190	150	100	Japanese Standard: Design Speed x 6sec.
Transition Curves Required	-	Yes	Yes	No	No	No	
Max. Radius for use of a Transition Curve	m	1450	1050	-	-	-	SATCC: 0.145 x V^2
Spiral Length	m	R=400:L=123, R=500:L=98, R=600:L=82, R=700:L=70, R=800:L=62, R=900:L=55, R=1,000:L=49, R=1,100:L=45, R=1,200:L=41, R=1,300:L=38, R=1,400:L=35	R=300:L=100, R=400:L=75, R=500:L=60, R=600:L=50, R=700:L=43, R=800:L=38, R=900:L=34, R=1,000:L=30	-	-	-	SATCC: $0.0702V^3/(RC)$ C: Rate of increase in centripetal acceleration (m/s3): 1<C<3 (1.438 is recommended)
Max. Gradient (desirable)	%	3.0	4.0	6.0	6.0	6.0	
Max. Gradient (absolute)	%	5.0	6.0	8.0	8.0	8.0	
Min. Gradient (desirable)	%	0.5	0.5	0.5	0.5	0.5	
Min. Gradient (absolute)	%	0.3	0.3	0.3	0.3	0.3	Japanese Standard: Design Speed x 6sec.
Crest Vertical Curve (k-value)	k	105	60	31	18	12	
Sag Vertical Curve (k-value)	k	51	36	25	18	12	
Max. Superelevation (e)	%	8.0	8.0	8.0	8.0	4.0	
Normal Crossfall	%	2.5	2.5	2.5	2.5	2.5	
Shoulder Crossfall	%	4.0	4.0	4.0	4.0	4.0	
Right of Way	m	COI	COI	COI	COI	COI	Corridor of Impact (Construction Limit)

- Normal Wereda towns and Kebele towns are included in Urban/Pre-Urban.

For this recommendation, the Study Team fills in the gaps as follows.

2. Other Standards Recommendation

A. SATCC: not stipulated

B. AASHTO: Flat grades can typically be used without any problem on uncurbed highways where the cross slope is adequate to drain the surface water laterally. With curbed highways or streets, longitudinal grade should be provided to facilitate surface drainage. An appropriate minimum grade is typically 0.5 percent, but grades of 0.30 percent may be used where there is a high-type pavement accurately sloped and supported on firm sub-grade.

C. Japanese Standard: Flat grades are normally preferable, but long section with flat grade will create some problem. Surface water on road should be drained by cross fall, but surface water sometimes remains on road surface due to problems such as rainfall intensity, drainage size, etc. It is therefore usual to set vertical gradient at least between 0.3 and 0.5 percent.

3. Reasons of Recommendation of 0.3 %

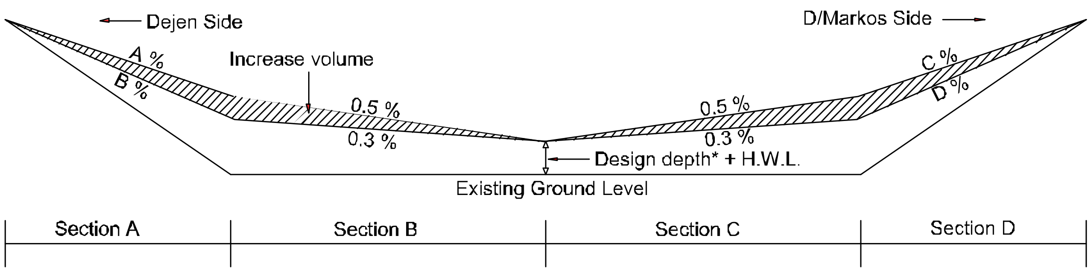
1) Livestock Corridor

Flat areas applied 0.3% min. gradient are currently being used as grazing land and/or livestock corridor. The study road may balkanize these areas and corridors by high embankment. For this reason, the embankments should be kept in low height as much as possible.

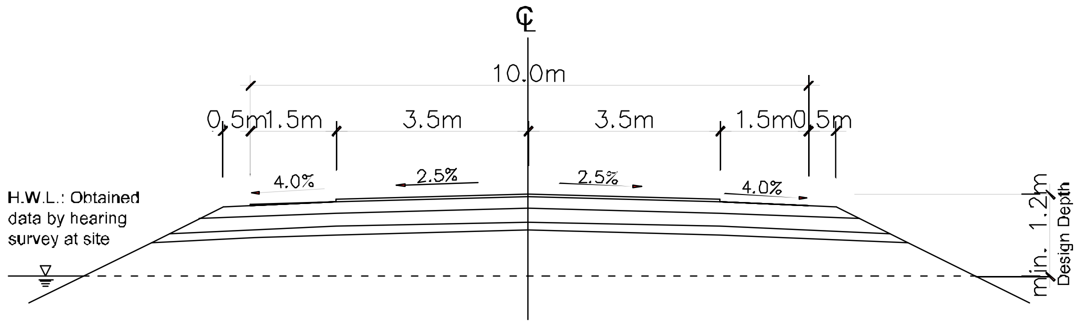
2) Reduction of Embankment Material

As mentioned previously, securing of min. 0.5% gradient in flat areas would mean a substantial increase in construction cost with the embankment material increase as follows:

Station											Gradient & Length				Total Increase Volume (m3)	Remark
											Sec.A	Sec.B	Sec.C	Sec.D		
0km+000	-	30km+510	0	+	200	-	1	+	200	1,000	2.65% / 300	0.33% / 700	- / -	- / -	7,496.10	Asametech
			11	+	0	-	12	+	420	1,420	1.60% / 220	0.30% / 1,200	- / -	- / -	28,840.20	Beket
			17	+	80	-	18	+	230	1,150	- / -	0.30% / 575	0.36% / 575	- / -	6,414.43	Taba
			21	+	280	-	23	+	220	1,940	- / -	- / -	0.30% / 1,220	2.02% / 720	40,320.18	Abeya
			25	+	580	-	26	+	920	1,340	4.54% / 310	0.40% / 405	0.30% / 390	3.79% / 235	2,922.05	Yegodena
Sub Total										6,850					85,993	
30km+540	-	65km+400	30	+	870	-	31	+	810	940	5.45% / 222	0.36% / 718	- / -	- / -	5,449.02	Rumame Behind of H.S.
			38	+	820	-	40	+	270	1,450	4.87% / 1,025	0.35% / 425	- / -	- / -	3,797.41	Godelma
			47	+	400	-	49	+	260	1,860	2.95% / 560	0.30% / 1,300	- / -	- / -	42,240.60	Yeda
Sub Total										4,250					51,487	
Total															137,480	



*Design depth: The design depth is defined as the depth from finished road level to the depth that load bearing strength of the soil no longer has an effect on the pavement's performance in relation to traffic loading. Following figure shows the design depth in relation to the main structural components of pavement and earthworks and it gives the design depth.



Flood and/or Flat Areas

Table: Standard for the Design Depth (i.e. Tanzania, S.A., Japan)

Tanzania Standard			S.A. Standard		Japanese Standard
Road Type	Design Depth (m)		Road Class	Design depth	
	General	Heavy Load			
Paved Trunk	0.8	1.2	A	1.0 – 1.2	1.0m from bottom of sub-base
			B	0.8 – 1.0	
Others	0.6	1.0	C	0.8	
			D	0.7	

4. Conclusion

From the results of study mentioned above, the Study Team recommend using gradient of 0.3% as minimum gradient under the following conditions based on AASHTO.

- To use asphalt concrete pavement: 10cm
- To set accurate slope (Cross slope)
- To support on firm sub-grade (well-compacted improved sub-grade)

Countermeasure for expansive soil on the Trunk Road A3 between Dejen and Debre Markos

1. Principle (ERA Site Investigation Manual 2002)

Mitigation measures for expansive soils are mentioned as follows in the Manual

(a) Realignment; this solution is possible only if the areas covered with expansive clays are of limited extent.

(b) Excavation and replacement; this simple procedure effectively eliminates the problems and is therefore recommended as much as possible. The investigations should focus on minimizing haulage of the materials, and this method will be economically viable only if suitable backfill material is available in the vicinity of the project road.

(c) Treatment with lime; treatment of expansive soils with hydrated lime can give good results. The addition of 4 to 6% of lime is usually required. This treatment is, however, costly, in particular because it is necessary to treat a substantial thickness of soil (minimum 30cm compacted thickness). Lime treatment would therefore be considered advantageous only where investigations failed to locate suitable backfill material.

(d) Minimizing Moisture Changes and Consequent Movements; if the above methods cannot be utilized, because of excessive costs or the absence of suitable backfill or replacement material, expansive clays may be used for fill and sub-grade. Special Practices are then necessary to avoid ingress of moisture into the road pavement that results in detrimental volume changes in the swelling soils. (Confining expansive clays under protective blankets, etc)

As the manual states, in case suitable backfill material is available, replacement procedure is applied as countermeasure for expansive soils. Since suitable backfill material is available in the vicinity of the project road, replacement method is preferable.

2. Thickness of soil replacement

Table-1 shows required replacement thickness stipulated in some countries' manual, recommended in some studies and adopted in some projects. ERA manual, Kenyan and SATCC manual mention maximum 1m as replacement thickness. Some U.S. state department procedure recommends 1.5m replacement thickness, and also 0.5 – 1.5m thickness was applied in Addis Ababa – Jima road. In the context of these manuals and experience, maximum replacement thickness is considered to be 1.5m.

Table-1: The provisions of manuals, performances and recommendations for replacement thickness for expansive soils

No	Name of manual	Description of the provision
1	ERA manual	It is usually considered sufficient to excavate the expansive soil to a depth of about 1m (even if some expansive soil remains under the backfill material, it will be confined and protected from moisture changes.) Such backfill material should exhibit strength (CBR) characteristics similar to those of the overlying embankment materials (preferably at least CBR on the order of 5, i.e. sub-grade strength class S3)
2	Zimbabwean Practice	Remove 700mm
3	Tanzanian practice	Remove 600mm
4	Kenyan manual	Recommends 1000mm
5	Indian case studies	Recommend removal of 1000mm
6	SATCC	Recommends 1000mm removal
7	Some U.S. state department procedure	Recommends removal up to 1500mm
8	CPC study in Ethiopia	Recommends 900 to 1200mm
9	Addis Ababa-Tarmaber project	Removed 800mm
10	Addis Ababa – Jima	•Removed 500 – 1500mm •Vertical barrier of LDPE sheeting (depth 2000mm)

3. Fluctuation area of water contents in expansive soil

The depth of moisture fluctuation is reported to be in the order of 2m to 3m, the Figure-1 shows the model of moisture fluctuation mechanism. Cracks develop from ground surface to maximum depth of about 1.5m according to some investigation. Moisture contents vary from ground surface to depth 3m as in Figure-1. Moisture content of ground surface increases with depth until about 3m during dry season, while it decreases during rainy season on the contrary. Moisture content below about a 3m depth is reported to be stable, and therefore does not fluctuate.

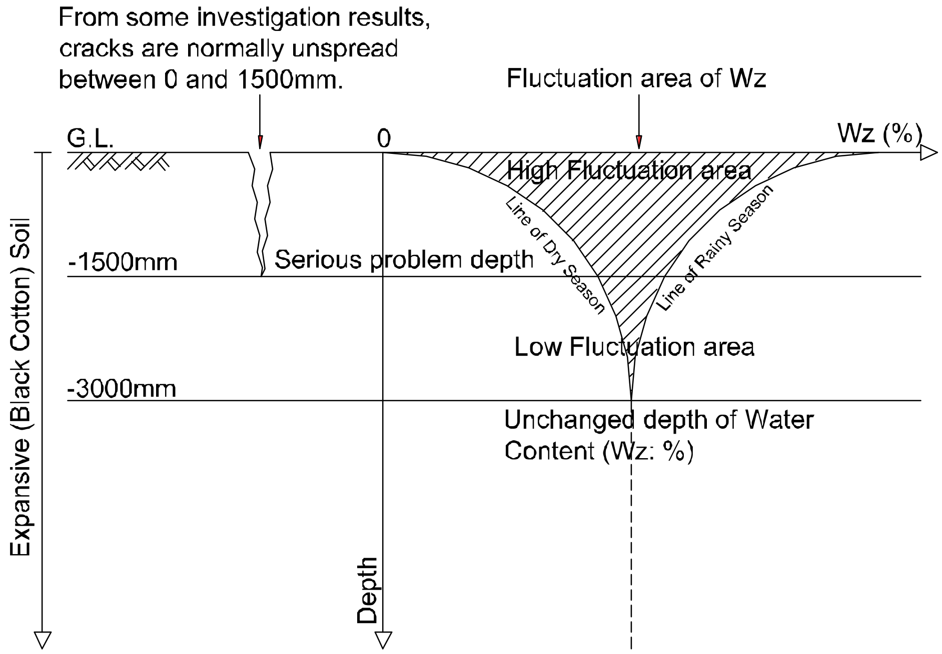


Figure-1: Extent of the Impact by BC Soil

4. Geological condition of project road

Geological conditions from Dejen to Lumame (30.5km) and from Lumame to Debre Markos (35km) are described in accordance with the results of test pits and borehole investigation in Tabel-2 and Table-3.

Expansive soil (BCS; Black cotton soil) is observed along the entire alignment between Dejen and Lumame. Most depths of BCS fall in the range 2 – 3m; however, some depths reach about 10m in Abeya river area where it is flooded sometimes during rainy season.

BCS is observed in some sections between Lumame and Debre Markos, and also depths of BCS in Yeda river area reach about 10m. Reddish and brown silty clay are observed over more than half of the section of 35km.

Table-2: Sub-grade condition between Dejen and Lumame

Boring or Pit	Chainage	Location	BCS	Red. / Brn	N value	CBR	Swell %	PI	NMC	S.L.	Eex
NTP 01	1+500		0.8-2.0		< 10			38			
NTP 02	4+000		0.6-2.6		< 10	2	10.0	51			112
NBH 01	5+060		1.0-2.5		8-9			77	39	3.2	
NTP 03	5+500		0.5-1.9		< 10			48			
BH 09	8+500	Yitnora	0.95-2.7		2-6			47			
NTP 05	9+500		0.8-2.8		< 10			46			
BH 10	10+500		0.0-2.0		3-10			36	31		
BH 11	11+400		0.0-4.0		4-9			25	40		
NTP 06	11+500		0.5-3.1		< 10			73			
BH 12	12+500	Bechet	0.5-2.5		1-6			52	46		
NTP 07	13+500		0.7-2.5		< 10	2	8.0	42			97
NBH 02	14+560		0.6-2.0		8			72	39	2.8	
NTP 08	15+500		0.8-2.5		< 10			62			
NTP 09	16+500		0.9-2.6		< 10			73			
NTP 10	17+500		0.6-2.4		< 10			74			
BH 13	18+500	Taba	0.0-3.0		1-4			78	51		
NTP 11	19+500	Wejel	0.5-2.4		< 10			47			
BH 14	20+000	Aba Adem	0.0-2.1		3-4			52			
NBH 03	20+090	Aba Adem	0.5-3.5		9-14			70	44	4,4	
NTP 12	21+500		1.1-2.4		< 10			51			
NBH 04	22+040	Abeya	1.0-13.0		2-9			51	46	7.3	
NBH 05	22+080	Abeya	1.0-11.0		4-11			53	44		
NTP 13	23+000		0.6-3.0		< 10	2	8.4	51			128
NTP 14	24+000		1.6-2.5		< 10			57			
NTP 15	26+500		0.8-3.0		< 10	2	12.4	43	53	9	90
NBH 06	26+500		0.6-2.5		4-5			52	53	6.2	
NTP 16	27+500		0.7-2.7		< 10			71			
NTP 17	29+000		0.5-3.0		< 10			63			
NBH 07	29+300	Bogena	0.6-3.9		10			43	31		
NBH 08	29+390	Bogena	1.0-3.9		5-6			70	61		
NPT 18	30+000		1.1-3.0		< 10			59			

Note; BCS: Black cotton soil, Eex: Expansiveness

Table-3: Sub-grade condition between Lumame and Debre Markos

Boring or Pit	Chainage	Location	BCS	Red. / Brn	N value	CBR	Swell %	PI	NMC	S.L.	Eex
NTP 19	32+000		-	Red		9	1	43	35	14	81
NTP 20	34+500		-	Brn				46			
NBH 09	35+670	Getla									
NTP 21	36+000		0.0-1.3		< 10			50			
NTP 22	37+500		0.0-1.4		< 10			54			
NTP 23	38+500		0.5-2.7		< 10			32			
NTP 24	40+500		-	Red				28			
NTP 25	42+500		-	Red		9	1.2	28	31	17	33
NTP 26	43+500		-	Red				25			
NBH 10	44+060		-	Red	> 12			21	35	15	
NTP 27	45+500		-	L/Brn				24			
NTP 28	46+500		-	D/Brn				40			
NBH 11	47+420	Yeda	0.0-5.5		4-10			57	35	6.8	
NTP 29	48+000	Yeda	> 4.0		< 10			58			
NBH 12	48+900	Yeda	0.0-10		5-10			40	43	7.8	
NBH 13	49+200	Yeda	0.0-10		1-9			32	49	10.7	
NTP 30	49+500	Yeda	> 4.0		< 10	2	7.9	43	36	14	81
NBH 13-2	50+200	Yeda	0.0-2.4		4-10			54	37	2.5	
NTP 31	50+500	Yeda	0.0-2.7		< 10			44	46	13	85
NTP 32	51+500		-	Red				37			
NTP 33	53+000		-	L/Brn				22			
NBH 15	53+500	Ambesh	-	D/Brn							
NTP 34	55+000		-	Red				38			
NTP 35	56+500		-	D/Brn		4	3.8	31	41	14	49
NTP 36	57+500		-	Red				39			
NBH 16	57+890	Chemoga	-	L/Brn	2-8			31	45		
NBH 17	58+020	Chemoga	-	L/Brn	> 11			40	35		
NTP 37	59+000		-	Red				36			
NTP 38	60+500		-	Red				23			
BH 19	61+000	Wiseta	-	Red	2			27	44		

Note; Red; Reddish silty clay, L/Brn; Light brown silty clay, D/Brn; Dark brown silty clay

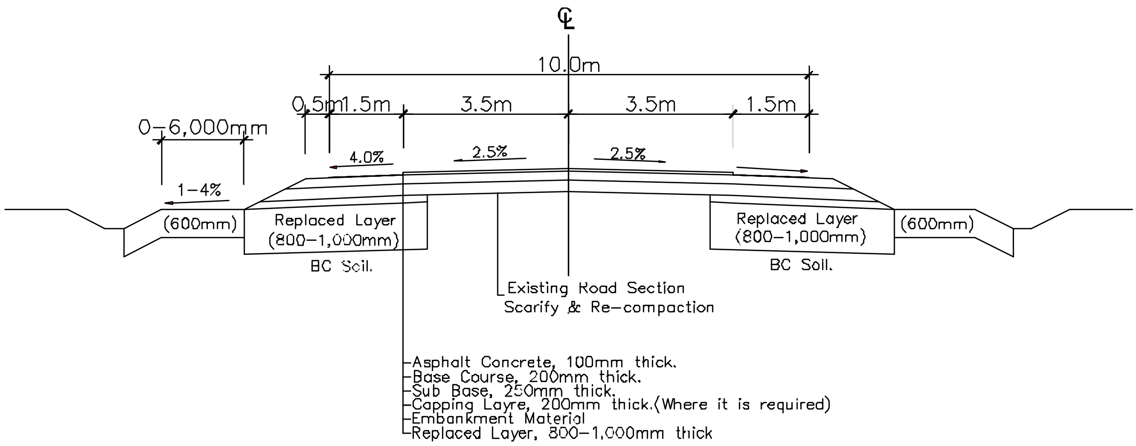
5. Alternative replacement procedures

Three alternative replacement procedures are presented.

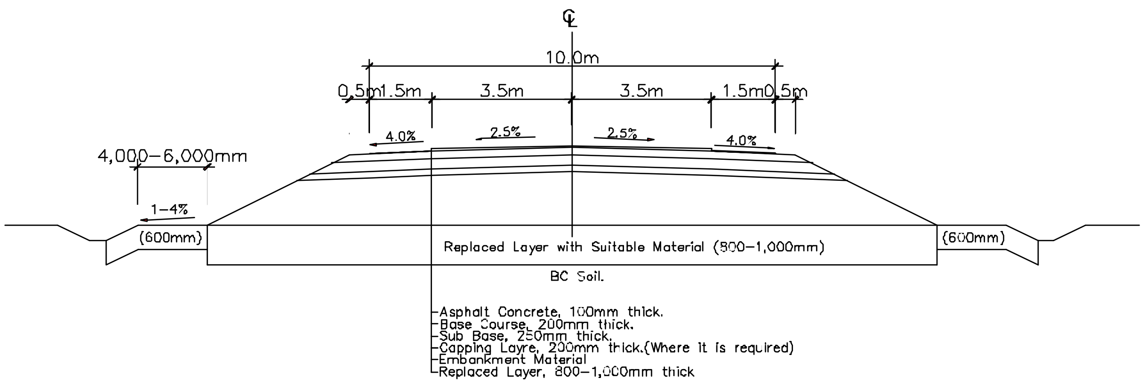
Alternative-1 (Figure-2) is proposed based on standard concept of some manual in which replacement thickness of 1.0m under road embankment and thickness of 0.6m horizontal blanket with width 0.0m-6.0m outside both embankment toes are designed. The replacement backfill with thickness of 0.6m on both sides functions to prevent the change of moisture content through the ground surface.

Alternative-2 (Figure-2*) is the same concept of replacement but with a thickness of 1.5m under road embankment and thickness of 0.6m on both sides of embankment toes.

Alternative-3 (Figure-3) has replacement thickness 1.0m under road embankment and vertical barriers on both sides which function to prevent the change of moisture content and confine it instead of horizontal blanket employed in Alternative-1 and -2. Vertical barrier depth of 3.0m is planned by considering fluctuation area of water content (refer to Figure-1). This vertical barrier depth of 3.0m is planned to be adopted for Abeya and Yeda river area. Depth of vertical barrier will be varied depending on BCS thickness in other locations.



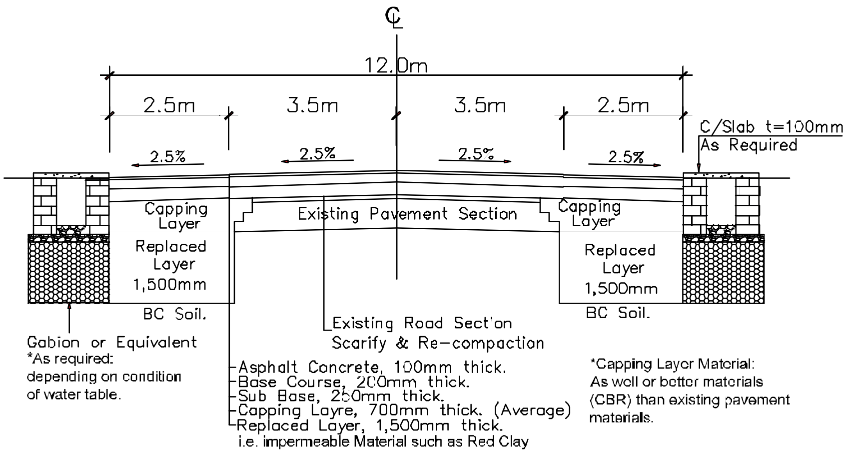
Existing Pavement Section in Rural Area



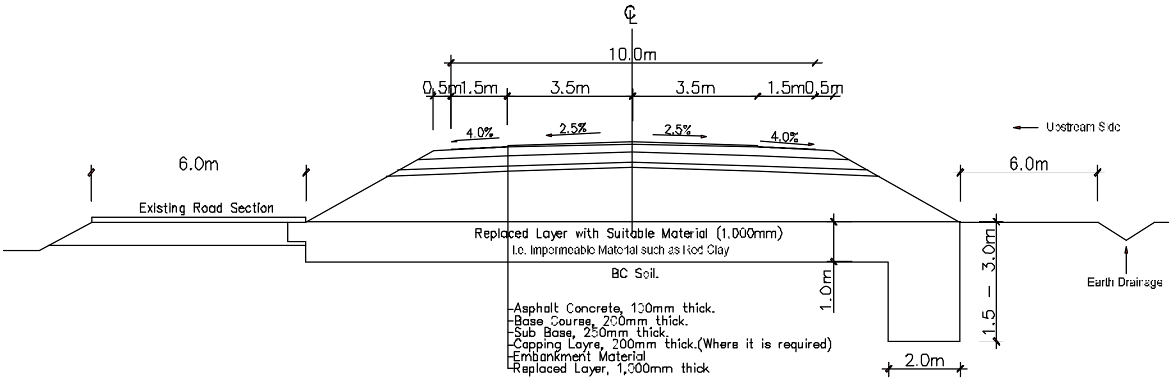
New Road Section (Bypass) in Rural Area

Figure-2: Countermeasure Concepts based on ERA Design Manual

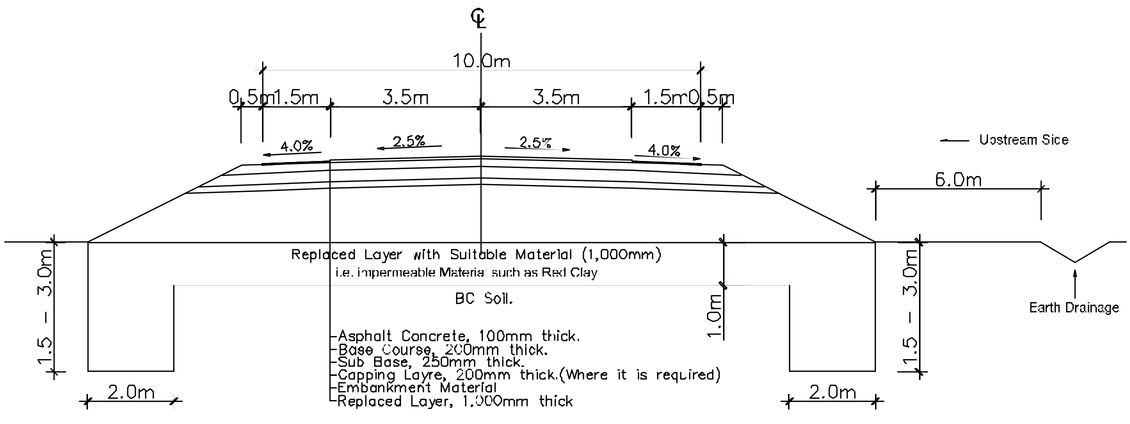
*Alternative 2, the replacement thickness is changed from 1.0 to 1.5 in Figure-2.



Existing Road Section in Town Area



Existing Road Section in High Embankment (Rural) Area



New Road Section (Bypass) in Rural Area

Figure-3 Countermeasure Concepts Proposed by the Study Team

6. Recommendation

Table-4 shows advantages and disadvantages of the three Alternatives. Only Alternative-3 can be applied for countermeasure to expansive soils in Abeya and Yeda river area, therefore Alternative-3 is recommended as the most appropriate procedure on the project road.

Table-4: Comparison of replacement methods and recommendation

No	Section	Replacement thickness: Under embankment: Carriage way	Replacement thickness: Under embankment: Toe	Replacement thickness: Slope protection	Application to Abeya & Yeda	Measures to gap between existing road and widened part	Side protection to moisture change	Recommendation
1	Realignment	1m		0.6m (L; ～6m)	Not suitable	—	Enough	
	Rehabilitation of existing road	—	1.0m	0.6m (L; ～6m)	—	Not enough	Enough	
2	Realignment	1.5m		By thickness	Not suitable	—	Enough	
	Rehabilitation of existing road	—	1.5m	By thickness	—	Enough	Enough	
3	Realignment	1.0m	～ 3.0m	By thickness	Suitable	—	Enough	Recommendable
	Rehabilitation of existing road	—	1.5m	By thickness	—	Enough	Enough	

Note: The maximum thickness of soil replacement is 1.5m according to many Manuals and experiences.

Ref. No.ERA/ADM/101126/PO

Date: 26 November 2010

Ms Hiwot Mossisa
Central Region Directorate, Acting Director
Ethiopian Roads Authority (ERA)
Addis Ababa

Dear Madam,

RE: PROPOSED ROAD ALIGNMENT AT CHEMOGA AND CROSS SECTIONS WITHIN DEBRE MARKOS
ON
THE PROJECT FOR REHABILITATION OF TRUNK ROAD, PHASE IV

We would like to draw your attention to the aforementioned project and previous meetings we have held in October, 2010 in your office at Alemgena on the subject matter referenced above. We also would like to refer to our previous letter with Ref. No. ERA/ADM/101022/PO dated 22nd October, 2010. In the letter some pending issues were listed in a table form No. 1 to No.5. Issues No. 1 and No. 5 were tackled in our letter with Ref. No. ERA/ADM/101025/PO dated 25th October, 2010.

But issues No. 2, No. 3 and No. 4 were still pending as we were waiting for the conclusion of detail topographic survey. The detail topographic survey was completed on 5th November, 2010 and now we present our study results and proposals based on the acquired topographical survey data.

Our explanation aims at resolving the issues of Road Alignment at Chemoga (Sta. 58+000 ~ 58+700) and Applicable cross sections in Debre Markos Town (Sta. 60+800 ~ 65+400), including road width and median width.

For details please refer to the attached document titled "*Discussion for the Design Conditions and Concepts*"

We therefore request for your evaluation and approval of our proposals made in this letter for the expeditious progress of the design work.

Yours sincerely,

Masaaki TATSUMI Dr. Eng
Oriental Consultants Company Limited
JICA Study Team, Chief Consultant

Cc: Mr. Abdo Mohammed,
DDG Engineering & Regulatory Department,
Ethiopian Roads Authority.

Discussion for the Design Conditions and Concepts

In a series of previous meetings, following matters were left as pending issues.

- Road alignment at Chemoga
- Applicable cross sections in Debre Markos Town

We hereby report results of the study based on the data of the detail topographic survey completed on 5th of November.

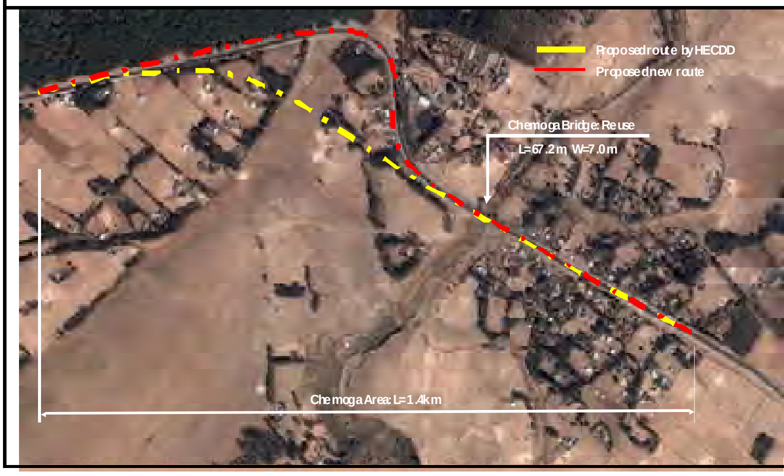
1. Alignment Change at Chemoga

(1) Outline of Alignment Change

Design Condition: Urban/Peri-urban

- Design speed: 50km/h
- Min. Radius: 85m
- Transition curve: not required
- Max. Grade: 8.0%
- Min. Stopping Sight Distance: 55m

Table-1

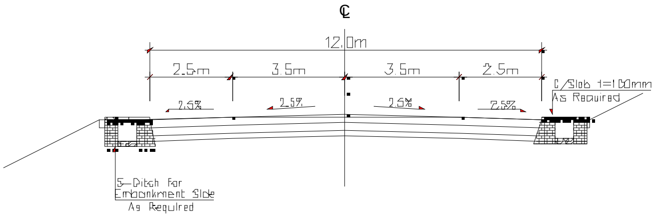
Location	Reasons & Interferences
	Chemoga Area 58.0 – 59.4km (L=1.4km) **Reason** - To reduce the number of affected houses **Interference** - Some houses

(2) Recommendation

New road construction would mean a commensurate increment of affected area and houses. Although horizontal alignment is improved by new construction road, it makes vertical alignment worse. On the other hand, existing route provided gentler grade in comparison to new road alignment. In addition, stopping sight distance for design speed of 50km/h is also satisfied. Thus upgrading of existing route (proposed new alignment) is recommended as much as possible.

(3) Result of the Study based on Detail Topographic Data

Table-2

		HEC Alignment	New Alignment
Geometric	Min. Radius	270m	100m
	Max. Grade	8.0%	5.8%
	Applicable design speed	50km/h	50km/h
	Regulatory Speed	30 – 50km	
	Calculated Sight Distance	111m > 55m	68m > 55m
Applicable Cross Section			
No. of affected houses		3	0
Land required	Road reserve	New land is required because of new road construction	Width of upgraded road will be within existing road reserve area.
	Diversion during construction stage	It is not required because of new construction road.	Diversion with 6m will be provided by use of a part of ERA's land.

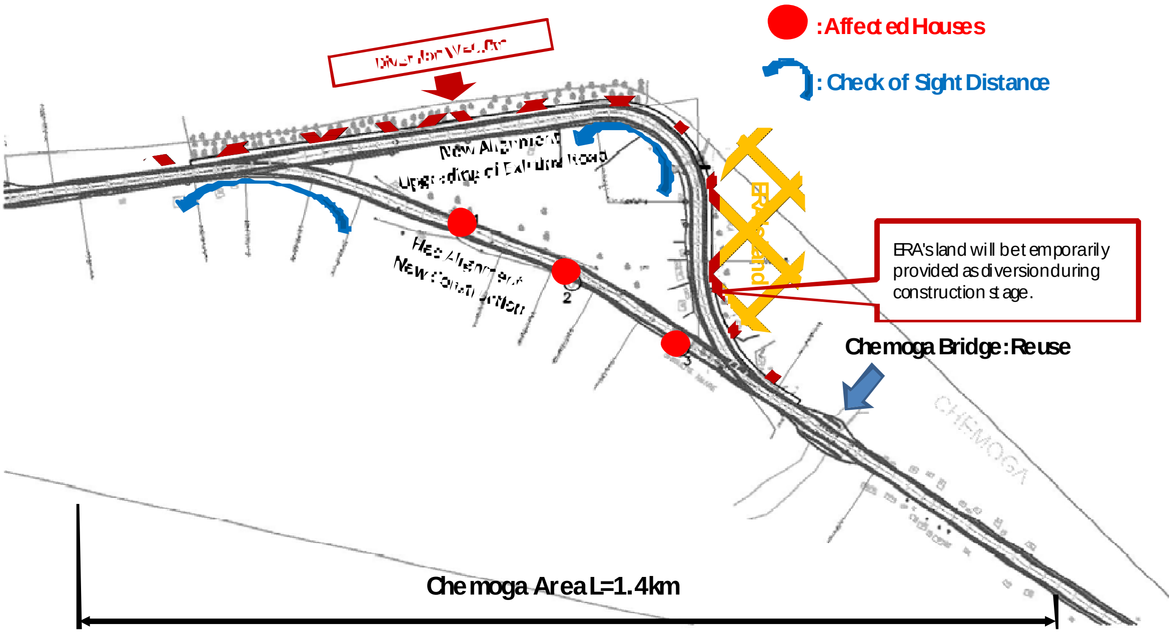
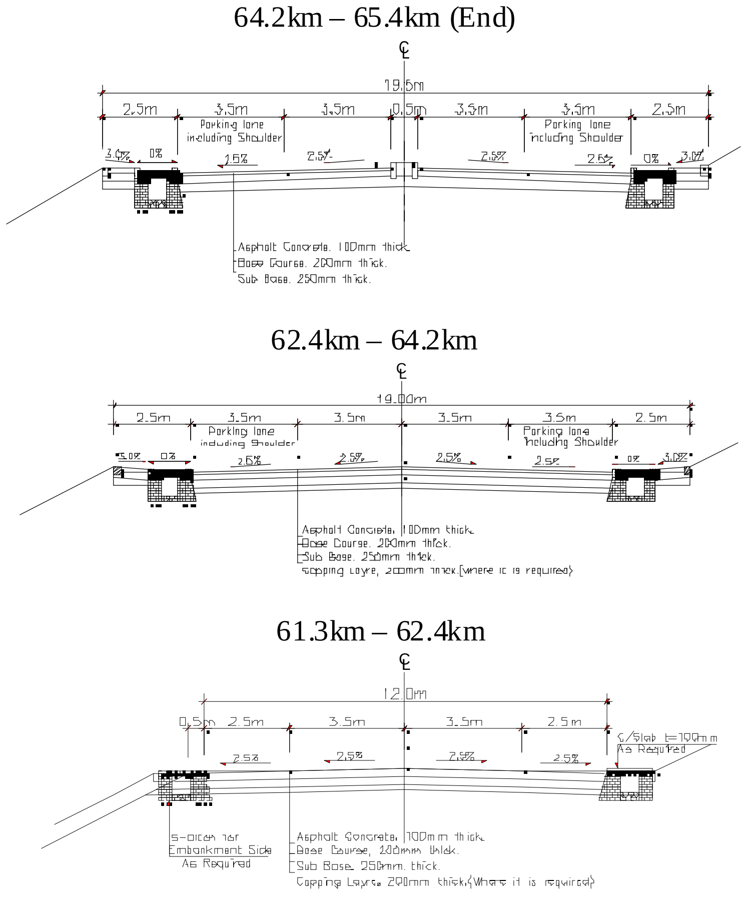


Figure-1 Comparative Illustration at Chemoga

2. Applicable Cross Sections in Debre Markos

(1) Recommended Cross Section on Previous Meeting

Table-3

Section Plan for A3 in Debre Markos	Applicable Cross Sections
	

(2) Result of the Study

In report of previous meeting, beginning point of D/Markos was set at diverging point of A3 and city road proposed by HEC. However beginning point of D/Markos was specified to be at the entrance of small village (see Table-4 in next page) in the meeting. Thus length of D/Markos section is extended from 4.1km (Sta.61.3-65.4) to 4.6km (Sta.60.8-65.4).

Table-4 Relation of Number of Affected Houses and Road Width

<table>
<tr><th rowspan="2">Section Plan for A3 in Debre Markos</th><th colspan="5">Number of Affected Houses: W=*</th></tr>
<tr><th>12.0m</th><th>19.0m</th><th>19.5m</th><th>20.0m</th><th>21.5m</th></tr>
<tr><td rowspan="5">
</td><td>2</td><td>3</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>0</td><td>4</td><td>4</td><td>4</td><td>9</td></tr>
<tr><td>0</td><td>5</td><td>6</td><td>10</td><td>16</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td></tr>
</table>

***W: Total Width of Typical Cross Sections (see Appendix-1)**

(3) Recommendation of Applicable Cross Sections

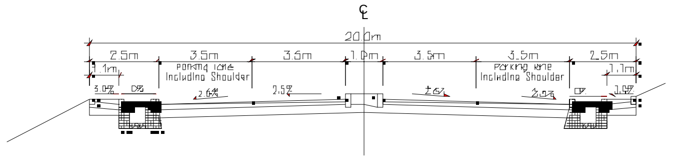
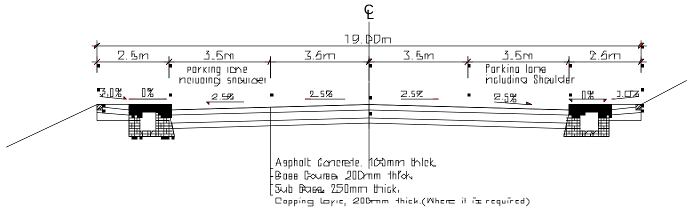
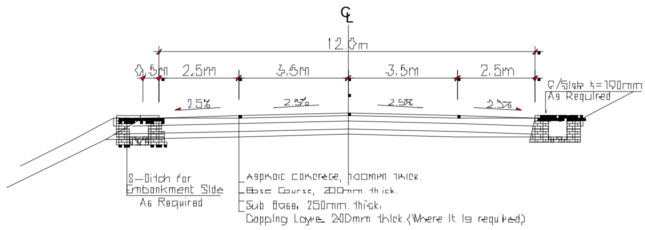
Cross sections in Debre Markos should be proposed in consideration of following three mattes:

- To minimize the adverse social impacts (minimization of number of affected houses)
- To respond to expansion of the city area
- To respond to parking demand

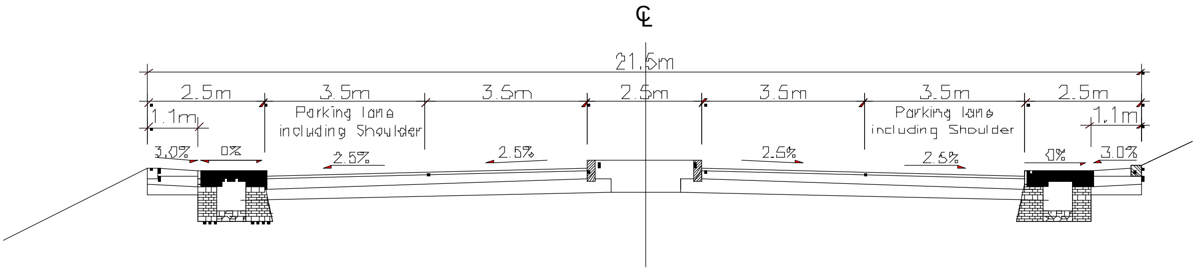
Of issues listed above, considerable expansion area of the city in the immediate future will be up to Wiseta River. For these reasons, following cross sections are recommended to be applied in Debre Markos (refer Table-5)

.

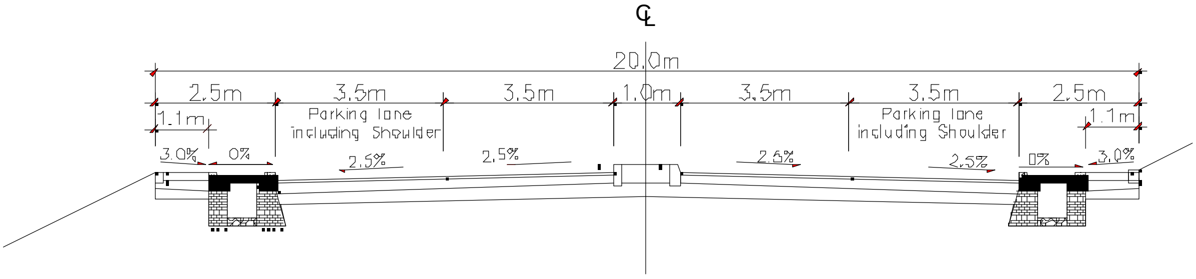
Table-5 Recommendation of cross sections and in Debre Markos

Section Plan for A3 in Debre Markos	**Applicable Cross Sections**
	64.1km – 65.4km (End): L=1.3km  61.6km – 64.1km: L=2.5km  60.8km – 61.6km: L=0.8km 

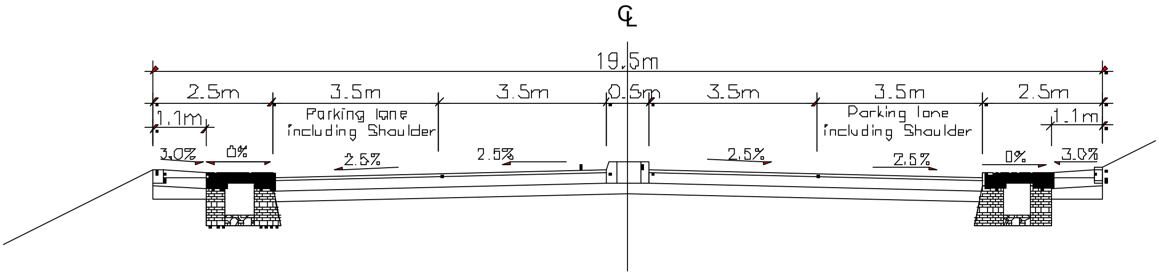
Appendix-1



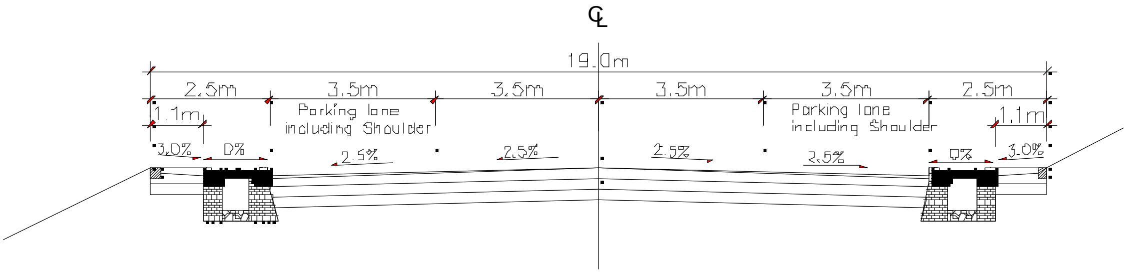
W=21.5m (Proposed by HEC DD)



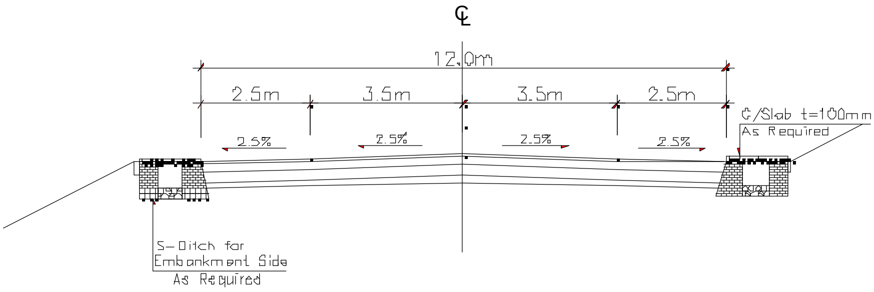
W=20.0m (Median Strip: 1.0m)



W=19.5m (Median Strip: 0.5m)



W=19.0m (No Median Strip)



W=12.0m

Appendix-2

Table: Number of Affected Houses (Whole Sections)

Sections		Width	DD Route by HEC	Proposed New Alignment	
			PAHs	PAHs	PAPs
Sta.00+000-00+500	Dejen	12.0m	8	0	0
Sta.06+800-09+100	Yetnora	12.0m	9	0	0
Sta.18+600-20+200	Wejel	19.0m	24	1	5
Sta.28+700-30+400	Lumame	19.0m	9	5*1	0
Sta.30+400-39+300	Unpopulated Area	10.0m	3	2	8
Sta.39+300-39+900	Gudalema	12.0m	1	0	0
Sta.45+720-46+800	Amber	19.0m	ND	16	70
Sta.46+800-52+000	Unpopulated Area	10.0m	1	2	10
Sta.52+000-52+900	Filiklik	12.0m	ND	0	0
Sta.58+000-59+400	Chemoga	12.0m	11	0	0
Sta.59+400-60+900	Unpopulated Area	10.0m	9	0	0
Sta.60+900-61+700	D/Markos	12.0m	84	1	5
Sta.61+700-64+200		19.0m		5	24
Sta.64+200-65+500		20.0m		8	37
Total			159	40	159

＊1: Kiosk

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የኢትዮጵያ መንገዶች ባለሥልጣን

ፖስታ ሣጥን ቁጥር 1770 አዲስ አበባ ኢትዮጵያ
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ቴሌክስ 211880 የስልክ ቁጥር 551-71-70/79
ፋክስ 251-11-5514866

THE FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA

ETHIOPIAN ROADS AUTHORITY

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Fax 251-11-5514866

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Ref. No. CR/MM3/1/3-3

Addis Ababa 27/12/2010

To: The Consortium of Oriental Consultants Co., Ltd. and
Eight-Japan Engineering Consultants inc.
Addis Ababa, Ethiopia

Re: The Project for Rehabilitation of Trunk Road, Phase IV
Dejen – Debre Markos

Subject: Proposed Road Alignment at Chemoga and Cross Sections within Debre - Markos Town

Dear Sir,

This is in reference to your letter Ref. No.. ERA/ADM/101126/PO dated November 26, 2010 through which you have forwarded your recommendation on the proposed road alignment at Chemoga and cross sections within Debre Markos town for our comment and subsequent endorsement.

Having reviewed your proposal, we have found that the proposed alignment at Chemoga is acceptable. However, we have noted the following comments to be incorporated in the proposal for the cross section in Debre Markos town.

- Provision of median strip is essential to minimize traffic accident by separating traffic movement in each direction and providing space at the mid of carriage way for pedestrian crossing the road. Considering the density of population for section 2 (0.8 km to 3.3 km) and the number of affected houses as per your proposal, we suggest to increase the typical section from 19.0m to 19.5m.

- In table 4, it is stated that the affected house with 19.5m width will be 3 and 4 for section 1 and section 2 respectively. Does it take into consideration the width of the side slope?

- For the beginning of Debre Markos town section, 800m, 2.5m parking lane have been recommended. However, if 0.7m clearance is provided for moving vehicles on both sides, total width which can accommodate two vehicles simultaneously will be 6.6m (taking on average 2.6m of vehicle width). Hence, providing 2.5m parking lane shall not be functional and thus we recommend the parking lane to be at least 3m from safety point of view.

- In most cases, there is a problem of proper design of junctions and vehicular crossings at town sections. Hence, please be advised to include detail junctions and vehicular crossings in the town sections.

.../2

In connection with the above, we have learnt from other ERA's projects across the country that the above listed shortfalls had created complaints from the local residents during the construction period. For that reason, we are of the view that it is better to entertain the aforementioned problems at the design stage which would help us to meet the demands of the local residents. Therefore, we would like to advise you to consider the cited comments in your subsequent submission of revised proposal for our endorsement.

Sincerely Yours,

Hiwot Mosisa
Central Region Directorate
Director

The Project for Rehabilitation of Trunk Road, Phase IV
(Dejen – Debre Markos Section)
The Consortium of Oriental Consultants Co., Ltd.
and Eight-Japan Engineering Consultants Inc.

ORICONSUL

Ref. No.ERA/ADM/110117/PO

Date: 17 January 2011

Ms Hiwot Mossisa
Central Region Directorate, Director
Ethiopian Roads Authority (ERA)
Addis Ababa

Dear Madam,

RE: PROPOSED ROAD ALIGNMENT AT CHEMOGA AND CROSS SECTIONS WITHIN DEBRE MARKOS
ON
THE PROJECT FOR REHABILITATION OF TRUNK ROAD, PHASE IV

This is in reference to your letter with Ref. No. CR/MM3/1/3-3 dated 27th December, 2010 through which you have noted the comments for the cross section in Debre Markos town.

Having studied and discussed your requests and comments with JICA headquarter, we would like to reflect them to the project as follows:

1. Cross section
   - Section 1 (3.3 – 4.6km, 64km+100 – 65km+400, L=1.3km) ; W=20m with median strip 1.0m
   - Section 2 (0.8 – 3.3km, 61km+600 – 64km+100, L=2.5km) ; W=19.5m with median strip 0.5m
   - Section 3 (0.0 – 0.8km, 60km+800 – 61km+600, L=0.8km) ; W=13.0m with parking lane 3.0m

   Please refer to the attached figure.

2. The width of the side slope was taken into consideration for cross section 20.0m of Section 1 and 19.5m of Section 2.

3. A left-turn lane will be incorporated at the intersection 61km+300 & 64km+750 for vehicular crossing at town sections, and the concept plan will be drawn in the report prepared in March.

We would like to request for your approval of our proposals for the project.

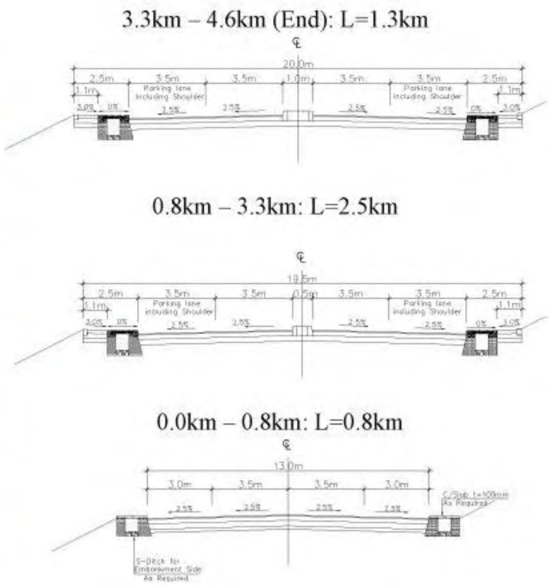
Yours sincerely,

Masaaki TATSUMI Dr. Eng
Oriental Consultants Company Limited
JICA Study Team, Chief Consultant

Cc: Mr. Abdo Mohammed,
DDG Engineering Operations Department,
Ethiopian Roads Authority.

12-1, Honmachi 3-chome, Shibuya-ku, Tokyo, 151-0071 Japan
Tel. +81-3-6311-7894 Fax. +81-3-6311-8043 Cell: 0912 964 852 E-mail. tatsumi@oriconsul.com

Appendix ;

Section Plan for A3 in Debre Markos	Applicable Cross Sections
	

Cross section of Debre Markos Town

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ቴሌክስ 211880 የስልክ ቁጥር 551-71-70/79
ፋክስ 251-11-5514866

THE FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA

ETHIOPIAN ROADS AUTHORITY

Post Office Box 1770 Addis Ababa Ethiopia
Cable Address Highways Addis Ababa
Telex 211880 Tel. No. 551-71-70/79
Fax 251-11-5514866

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Ref. No. CR/MMB/1/16-3

Addis Ababa 26/1/2011.

To:	The Consortium of Oriental Consultants Co., Ltd. and Eight-Japan Engineering Consultants inc. Addis Ababa, Ethiopia
Re:	The Project for Rehabilitation of Trunk Road, Phase IV Dejen – Debre Markos
Subject:	**Approval for the Proposed Road Alignment at Chemoga and Cross Sections within Debre - Markos Town**

Dear Sir,

We have made a reference to your letter Ref. No. ERA/ADM/110117/PO dated January 17, 2011 whereby you have sought our endorsement for the proposed road alignment at Chemoga and typical cross sections within Debre Markos town that incorporates our comments.

Accordingly, we have reviewed the revised proposal and found it acceptable. Hence, we have no objection for the proposed road alignment at Chemoga and typical cross sections within Debre Markos town.

Sincerely Yours,

Hiwot Mosisa
Central Region Directorate
Director

* EFDR ERA Central Region Directorate

6.2 Minutes of Meeting about RAP

Ref.No.በ3-138/00-16
Date 4/11/2009

From: The Amhara National Regional State Debre Markos
City Administration Mayer Office
To : Highway Engineering Consultants
Addis Ababa

Subject : Road Construction Works

We refer to our letter addressed to Ethiopia Road Authority of the engineering regulatory division 19/5/2009 with Ref.No.2526/በእ/00-18.In the letter we address ERA of the direction of the new road construction in Dejen town.
Currently, we understand that HEC is contracted for the consultancy service of the project by a letter sent to us with Ref.No. HEC/1991/09 and dated 02/11/2009.
Therefore, we request the route for the new road construction in the direction of Debre Markos district to Tekle-haimanot Square (old road).
Attached here with please find a minute signed by City Mayer Committee concerning the dicision of the road al/ Route in the Debre Markos town.

Signature and Seal
Abebaw Yaynwaga
Debre Markos City Mayor

Date 3/11/2009

Mayor’s Committee Minutes of Meeting

Attendants:

1. Mr. Migbaru Kebede Mayor’s committee chairperson
2. Mr. Alemahehu Tekeste Committee Member
3. Mr. Abebaw Yaynwaga »
4. Mr. Asmamaw Atnafu »
5. Mr. Tekel Yitayew »
6. Mr. Menberu Mengistu »
7. Mr. Dereje Denekew »
8. Mr. Melesachew Demelash »
9. Mr. Kefale Adinew »
10. Mr. Yohannes Amno »
11. Mr. Belaynew Tsega »
12. Mr. Mesfin Gesesse »

Agenda: Selection of road corridor/route in Debre Markos town

The Mayor’s committee has discussed and agreed on the following points:

1. The road segment in Debre Markos town should be wide and median separated and should be in accordance with the master plan.
2. The road should pass along the corridor from the Debre Markos District of ERA and Kebele 07 office and along the Mosque to the Tekle haimanot round about.

The reason for the above decision is as follows:

1. If the existing road is to be rehabilitated, it is going to be costly as there will be big volume of slope cutting and filling works.
2. The existing road horizontal alignment has many curves; therefore, number of accident will be high.
3. There are big building structures along the existing road; therefore, the amount of compensation will be extremely high. In addition, resettlement action will create an immense pressure on the people to be resettled and the city administration.
4. The terrain along the proposed alignment is more suitable for the road construction. In addition the construction of the road will bring an economic growth to all the people living along the road.

Therefore, we recommend the alignment of the road to be as agreed above for the reasons mentioned above. The above decision by the committee should be informed to the Design Firm by the name Highway Engineering Consultants PLC. The committee has already informed of its decision to ERA.

Signature of the committee members

Seal of the Debre Markos Town Administration

Date: 4/11/2009

Discussion to effectively carryout the Road construction Works from Dejen to Debre Markos
Time: 9:30 am
Place: Aneded Woreda Office

Attendants

1.	Mr. Abdulahi Mohammed	HEC
2.	Mr. Badeg Lake	Representative of Agricultural Office
3.	Mr. Abebaw Adane	» »
4.	Mr. Yalkibetal Admase	Representative of Aneded Woreda Administration
5.	Mr. Aderaw Abitew	Land Administration Office

Agenda: Concerning families that will be affected by the Road Construction Works

Mr. Abdulahi Mohammed: He said that he will make discussion concerning the compensation of farm land and houses with the concerned bodies. If a farm land or house is affected by the road works, we have to pay compensation according to the regulations. The road will have a width of 22m in towns.
Mr. Abebaw Adane: How is the road construction work go along with the Reservoir?
Mr. Badege Lake: Compensation must be paid for those affected by the road work.
Mr. Abebaw Adane: We have to make ready of ourselves anD/Deliver what is expected of us. Eventhough the people and the administration was expecting for long time, it is disappointing that the road is no going to pass through Aneded woreda village. Since the road is not going to pass through the village, the people are not going to benefit from the road construction. Therefore, the people will be disappointed anD/Distance themselves from the government.
Mr. Abdulahi Mohammed: Concerning the above, a discussion has to be made with the Designers,
the Zone and Regional Offices of ERA.
Mr. Badege Lake: We have to disscuss with a tangible information and we have to understand that the economic development of the village will be hindered. That is because the road is not passing through the Aneded woreda village.

Signature of the attendants
Seal of the Eastern Gojam Administration Zone
Aneded Woreda Trade & Industry Office

Date 4/11/2009

Preparation for necessary precautions to be taken for the Dejen Debre Markos Road Construction Project

Attendants:

1. Mr. Abdulahi Mohammed HEC (Chairperson)
2. Mr. Abebe Melese Awabel Woreda Administration
3. Mr. Kumilachew Damte Environmental Protection Agency
4. Mr. Edme alem Andualem Revenue Authority Office
5. Mr. Sima Kebede Awabel Woreda Municipality
6. Mr. Azeze Kasahun Women's Associaltion representative

Agenda:

1. Compensation Matter
2. How to consider affected people in urban and rural area

Minutes of meeting are as follows:

Mr. Abdulahi Mohammed: The Government will pay compensation to properties like farm land and houses that are affected by the road construction. He requested if there is any question from the people and administration so that HEC can accommodate the matter in the study.

Mr. Kumilachew Damte: According to government regulation a compensation will be paid for farmers who are affected. However property evaluation and paying the compensation money will take a very long time. So what are you thinking in this regard?

Mr. Abdulahi Mohammed: compensation will be evaluated and will be paid by Ethiopian Roads Authority so it is difficult to answer this question by HEC.

Mr. Azeze Kasahun: Is the road construction going to affect seriously specially the farmlands?

Mr. Abdulahi Mohammed: The road alignment is almost following the existing centerline around this village. Therefore farmlands are not going to be affected seriously.

Sign by the participants

Seal of the Amhara Regional Government, Western Gojam Administration

Awabel Woreda Administration Office

Date: 4/11/2009

Meeting Venue: Dejen Woreda Water Resource Office

Time: 2:00 pm

Attendants:

1. Mr. Abdulahi Mohammod HEC
2. Mr. Birilew Mossa Environmental Protection Agency
3. Mr. Melisew Tamiru Agricultural Office
4. Mr. Abedje Asamirew General Manager Municipality
5. Mr. Tamir Adam Land Administration Office

Agenda: Concerning resettlement and compensation for the Dejen Debre Markos Road Project

Minutes of Discussion

Mr. Tamiru: He suggested each and every property that will be affected should be identified with a photo of the property.

Mr. Melisew: For a farm land the type of crop, number of trees and productivity should be considereD/During the property evaluation stage and compensation.

Mr. Birilew: Farmers who have settled recently should be compensated according to the new regulation of the government.

Mr. Abeje: New construction near the road should be prohibited and the people should be informed about this.

Therefore, all participants have reached on agreement on the above issues unanimously.

Signature of the participants

Seal of the Amhara Regional Government, Eastern Gojam Administration

Dejen Town Municipality

6.3 Dam Plan of EEPCO

(1) Dam Plan of EEPCO

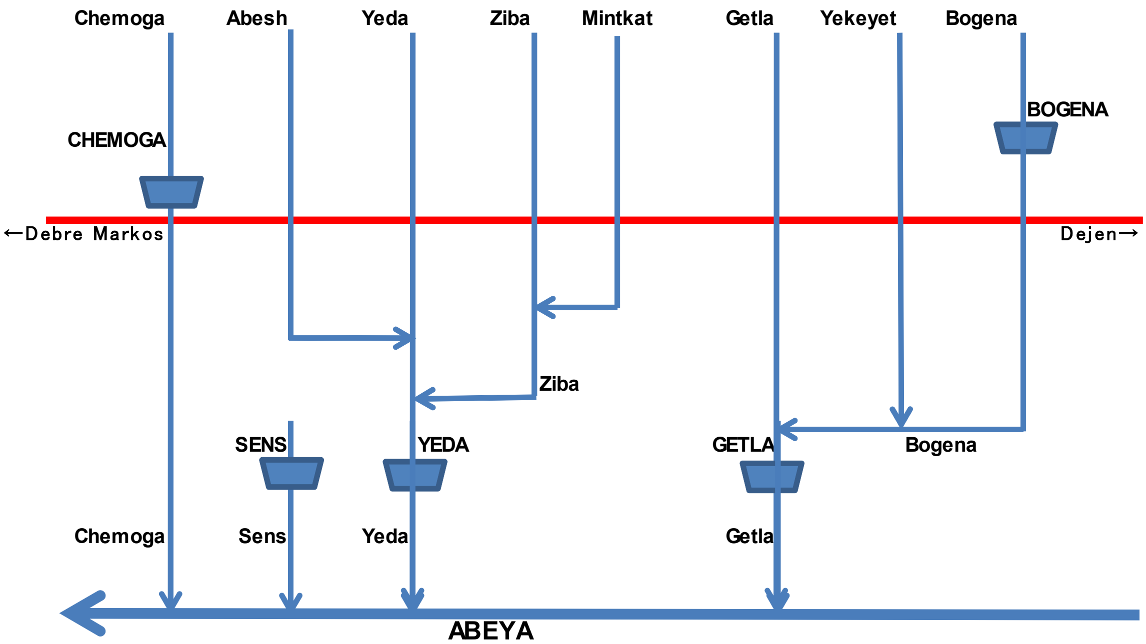
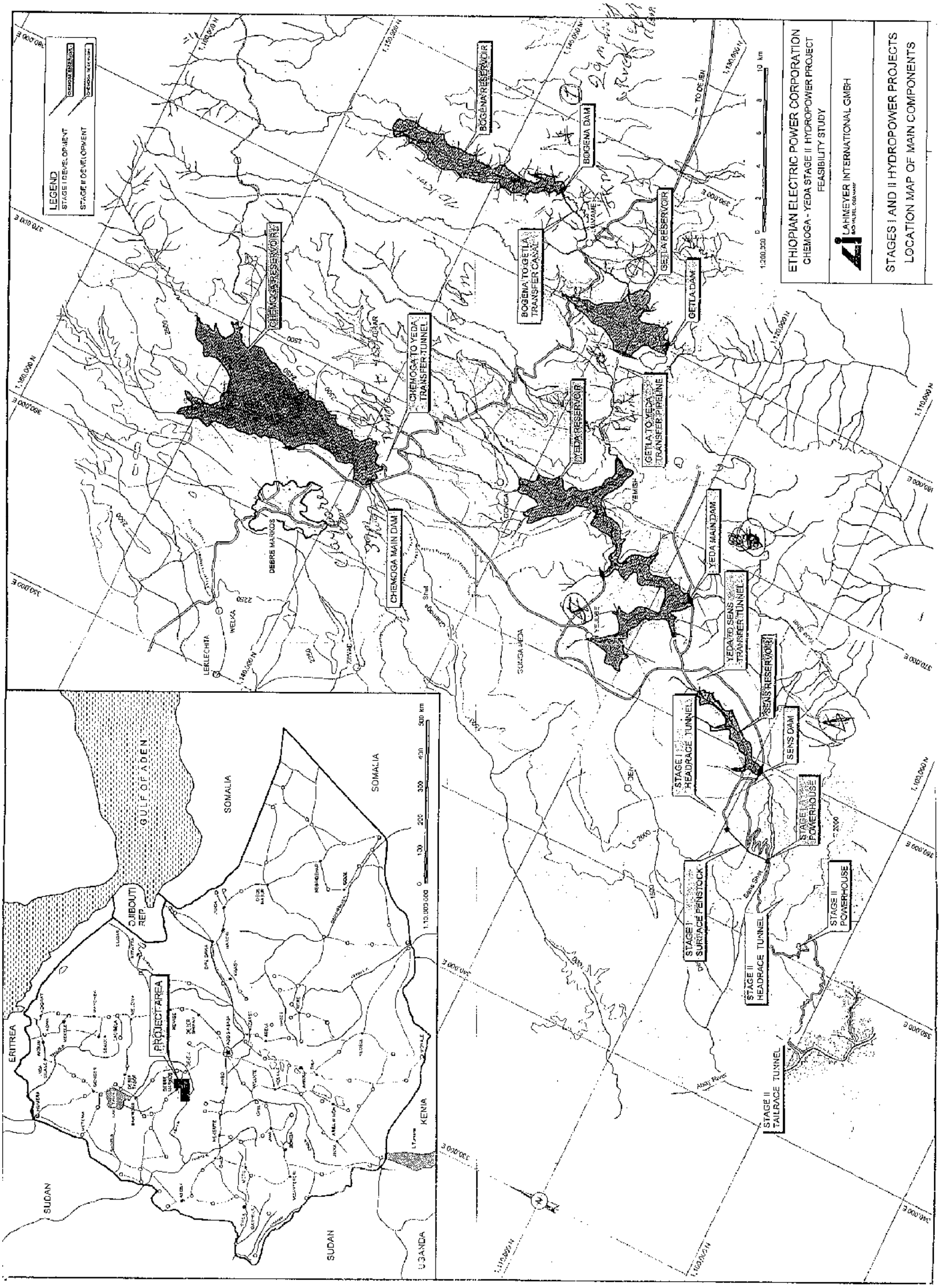
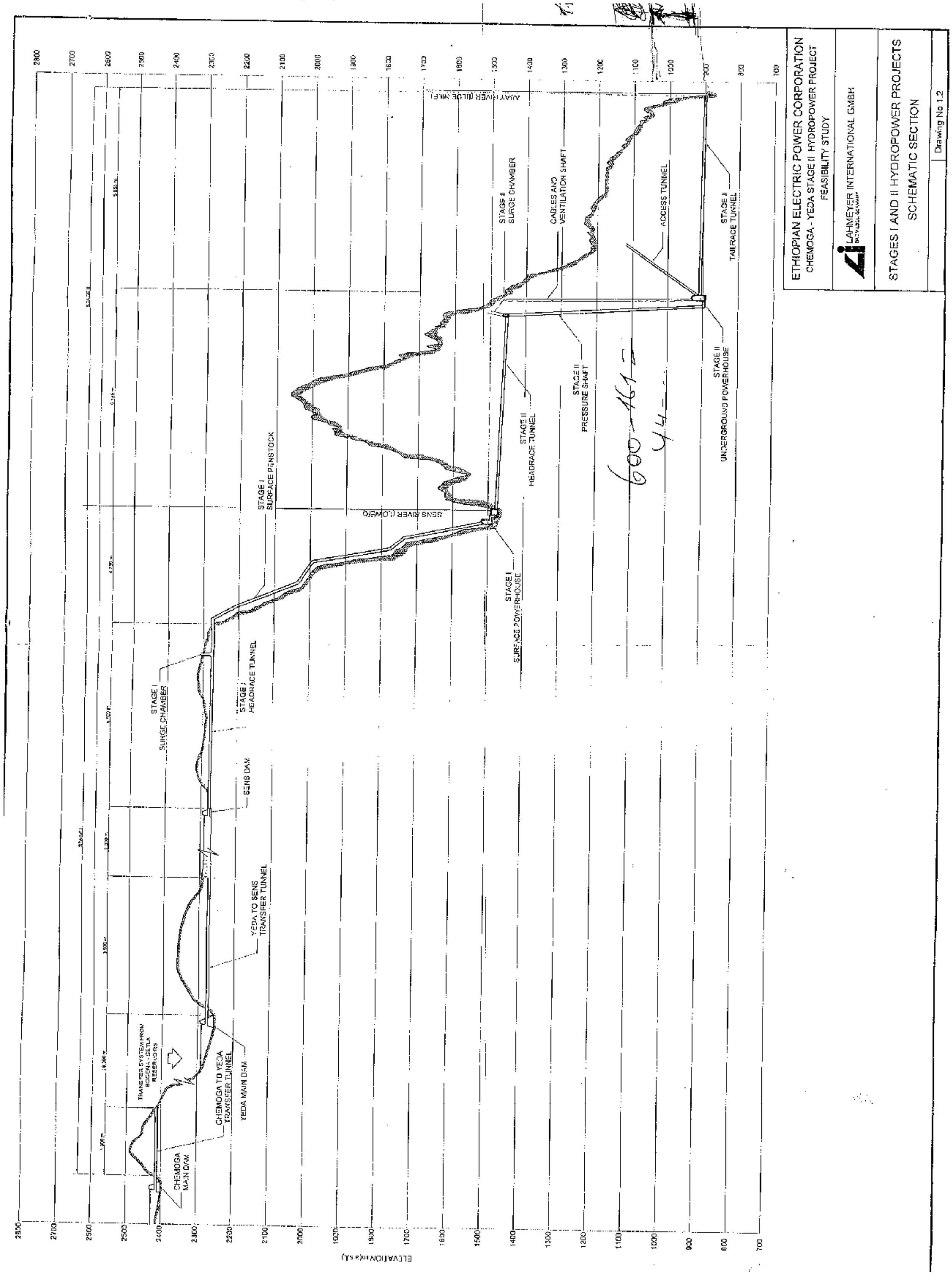


Figure 6.3.1 Overview Diagram dam project

(2) Plan of EEPCO Dam project



(3) Profile of EEPCO Dam project



6.4 Traffic analysis and prediction results（From ERA・D/D Report）

Table E1.1: Traffic Forecasted for Dejen - Debre Markos Road Project (2009-2032), Mixed Forecasted for Dejen - Debre Markos

Year	Car	4WD	S.B	L.B	S.T	M.T	H .T	T.T	TOTAL
2009	30	213	146	114	145	72	57	73	852
2010	33	226	159	124	157	78	62	79	918
2011	35	239	171	134	168	84	66	85	982
2012	37	253	185	144	181	90	71	91	1052
2013	39	268	200	156	194	97	77	98	1129
2014	53	363	276	215	266	133	105	134	1546
2015	55	384	298	232	286	142	113	145	1655
2016	59	407	321	251	307	153	121	155	1774
2017	62	430	346	271	330	165	131	166	1901
2018	65	455	374	293	354	177	140	179	2037
2019	69	481	404	316	380	189	150	192	2181
2020	73	510	437	340	408	203	161	206	2338
2021	77	535	468	364	435	217	172	219	2486
2022	81	561	498	387	461	230	182	232	2631
2023	85	587	530	413	488	244	194	246	2786
2024	89	615	564	440	517	258	205	262	2949
2025	93	643	601	468	548	273	217	277	3120
2026	98	673	641	499	581	290	230	294	3304
2027	102	705	682	531	616	308	244	312	3499
2028	107	738	727	565	653	326	258	330	3704
2029	112	773	773	601	692	345	273	350	3920
2030	117	809	823	641	734	366	290	371	4150
2031	122	847	877	682	778	388	308	393	4393
2032	128	886	934	727	824	411	326	416	4651

Source: Consultant's Traffic Survey and Forecast, 2009

6.5 Geological Survey

(1) Geological Survey

1) Purpose and Content of Survey

Geological Survey was carried out for the purpose of getting geological information to design and execution of the project road. Expansive soil named Black Cotton Soil is distributed along the route. One of the main objects of t is to clarify exact distribution, thickness and property of it. The survey includes next three items. It is as follows.

- Mechanical boring on the route.
- Test pitting on the route.
- Material survey for quarry and borrow pit.

2) Location and content of Survey

The location map is shown in Figure 6.5.1. The coordinate and distance of sites are shown in Table 6.5.1 and Table 6.5.2.

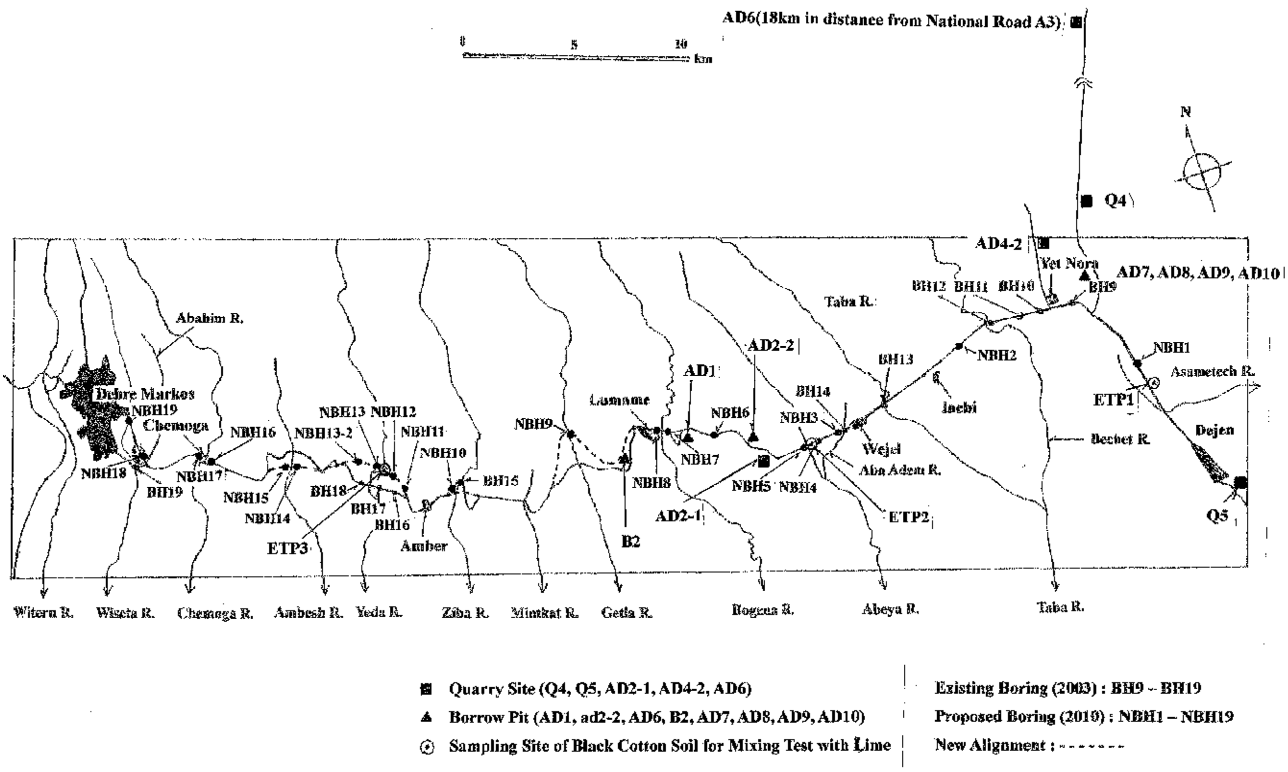


Figure 6.5.1 Location Map of Boring

Table 6.5.1 List of Boring Site

Serial №	BH.№	Station (Km)	Location	Position	Coordinate	
					Easting	Northing
1	NBH 1	5+060	Plateau	Shoulder of Road	405126	1129603
2	NBH 2	14+560	Plateau	Shoulder of Road	397343	1131876
3	NBH 3	20+090	Aba Adem R.	Shoulder of Road	392058	1130320
4	NBH 4	22+080	Abeya R.	Shoulder of Road	390283	1130122
5	NBH 5	22+330	Abeya R.	Shoulder of Road	390084	1130116
6	NBH 6	26+500	Plateau	Shoulder of Road	386666	1131970
7	NBH 7	29+300	Bogena R.	Shoulder of Road	384199	1133004
8	NBH 8	29+390	Bogena R.	Shoulder of Road	384111	1133033
9	NBH 9	35+670	Getla R.	Canceled	380318	1134466
10	NBH 10	44+060	Ziba R.	Shoulder of Road	374738	1133686
11	NBH 11	47+420	Yeda R.	Shoulder of Road	372535	1134368
12	NBH 12	48+900	Yeda R.	Natural Ground	371847	1135567
13	NBH 13	49+200	Yeda R.	Natural Ground	371612	1135729
14	NBH 13-2	50+200	Yeda R.	Natural Ground	370759	1136180
15	NBH 14	53+480	Ambesh R.	Canceled	-	-
16	NBH 15	53+500	Ambesh R.	Shoulder of Road	36143	1137118
17	NBH 16	57+890	Chemoga R.	Shoulder of Road	364521	1138417
18	NBH 17	58+020	Chemoga R.	Shoulder of Road	364408	1138490
19	NBH 18	60+860	Abahim R.	Shoulder of Road	361845	1139222
20	NBH 19	63+640	Wiseta R.	Shoulder of Road	361404	1141871

Table 6.5.2 List of Test Pit

Serial No.	Station (Km)	Location	Formation	Depth of TP (m)	Depth of DCP (m)	Coordinate	
						Easting	Easting
NTP 1	1+500	Plateau	BCS	2.0	5.1	405794	1126106
NTP 2	4+000	Plateau	BCS	2.4	6.5	405312	1128558
NTP 3	5+000	Plateau	BCS	2.7	4.7	405049	1130034
NTP 4	7+500	Hill	BCS	3.0	5.2	404001	1131710
NTP 5	9+500	Hill	BCS	2.4	5.0	403248	1132382
NTP 6	11+500	Plateau	BCS	2.5	3.7	400262	1132651
NTP 7	13+500	Plateau	URC	2.0	3.3	398345	1132259
NTP 8	15+500	Plateau	BCS	2.1	4.4	396479	1131540
NTP 9	16+500	Plateau	BCS	2.4	5.3	395529	1131232
NTP 10	17+500	Plateau	BCS	2.4	4.5	394568	1130955
NTP 11	19+500	Hill	BCS	1.4	2.9	392647	1130399
NTP 12	21+500	Lowland	BCS	2.1	5.3	390663	1130155
NTP 13	23+500	Hill	BCS	3.0	4.5	389168	1130038
NTP 14	24+000	Hill	URC	2.5	3.5	388434	1130527
NTP 15	26+500	Plateau	BCS	3.0	5.1	386666	1131963
NTP 16	27+500	Plateau	BCS	2.7	4.7	385807	1132387
NTP 17	29+500	Hill	BCS	3.0	4.1	384468	1132868
NTP 18	30+000	Lowland	BCS	3.0	3.7	383084	1133637
NTP 19	32+000	Hill	URC	2.5	3.9	382309	1132663
NTP 20	34+500	Hill	URC	3.0	3.0	381034	1133663
NTP 41	35+670	Lowland	URC	3.2	3.5	380318	1134466
NTP21	36+000	Hill	URC	2.5	2.7	380049	1134336
NTP22	37+500	Hill	BCS	2.7	1.9	379460	1133045
NTP23	38+500	Hill	BCS	2.7	2.9	405312	1128557
NTP24	40+500	Hill	URC	2.2	2.4	377275	1131559
NTP25	42+500	Hill	URC	3.0	4.8	375867	1132737
NTP27	45+000	Hill	URC	2.5	1.5	373855	1133439
NTP28	46+500	Hill	URC	2.5	3.8	372682	1133218
NTP29	48+000	Lowland	BCS	3.0	4.2	372449	1134930

Serial No.	Station (Km)	Location	Formation	Depth of TP (m)	Depth of DCP (m)	Coordinate	
						Easting	Easting
NTP30	49+500	Lowland	UBC	2.4	4.1	371094	1135753
NTP31	50+500	Hill	BCS	2.7	2.0	370494	1136336
NTP32	51+500	Hill	URC	2.4	2.0	369608	1136339
NTP33	53+000	Hill	URC	1.8	4.0	369607	1137014
NTP34	55+000	Hill	URC	1.0	2.1	366762	1136787
NTP35	56+500	Hill	URC	1.8	2.5	365900	1137161
NTP36	57+500	Hill	URC	2.0	4.9	364841	1138197
NTP37	59+000	Hill	URC	3.0	1.5	363493	1138706
NTP38	60+500	Plateau	URC	2.5	4.7	362131	1139006
NTP39	62+000	Plateau	URC	2.8	4.2	361868	1140312
NTP40	63+000	Plateau	URC	2.6	3.8	381429	1141731

BCS = Black Cotton Soil, URC = Upper Red Clay, UBC = Upper Brown Clay(Alluvial Soil)

- Field geological investigation (63 Km)
- Boring and Sampling for black cotton soil (3holes)
- Boring and Sampling in the flood area of Abeya River and Yeda River (6 holes)
- Boring for the foundation of projected bridges (9 bridges, 11 holes)
- Test Pitting and dynamic cone-penetrometer test (DCP) for Black Cotton Soil (44sites)
- Sampling for CBR test (10 sites)
- Boring and sampling for quarry (5 sites, 2 holes)
- Boring and sampling for borrow pit (8 sites, 2 1samples)
- Laboratory test for samples

3) **Quantity of Survey**

Quantity of survey for boring, test pit and Laboratory test are shown in Table 6.5.3, Table 6.5.4, Table 6.5.5, Table 6.5.6 and Table 6.5.7. Among the mechanical borings, borehole No.NBH9 in Getla River was canceled because of difficult transportation of machine by bad access in rainy season. So dynamic cone penetrometer test (DCP) was carried out instead of boring. Also, boring No NBH 14 in Ambesh River was canceled because of exposing hard basalt as basement on the bank.

Table 6.5.3 Quantity of Working and Laboratory Test (Dejen - Debre Markos)

Bore Hole	Location Depth (m)	Depth (m)	SPT	UDS	Specific Gravity	Moisture Content	Particle Size	Atterberg Limit	Unconfined Compression	Tri-axial Test	Consoildation	Shinkage	Rock Test
NBH1	Plateau Area	10.0	8	2	2	2	2	2	1	0	1	1	0
NBH2	Plateau Area	10.0	8	2	2	2	2	2	1	1	1	1	0
NBH3	Aba Adem R.	10.0	7	2	1	1	1	1	0	1	1	2	0
NBH4	Abeya R.	27.2	23	2	13	13	13	12	0	1	1	2	1
NBH5	Abeya R.	26.6	23	1	1	1	1	1	0	0	0	0	0
NBH6	Plateau Area	8.0	5	1	1	1	1	1	1	0	1	1	0
NBH7	Bonega R.	7.0	3	1	1	1	1	1	0	0	0	0	1
NBH8	Bonega R.	7.2	2	1	1	1	1	1	0	0	0	0	0
NBH9	Getla R.(Canceled)	-	-	-	-	-	-	-	-	-	-	-	-
NBH10	Ziba R.	12.2	8	2	2	2	2	2	1	1	1	1	0
NBH11	Yeda R.	27.0	25	2	2	2	2	2	1	1	0	1	0
NBH12	Yeda R.	30.0	25	2	2	2	2	2	1	1	1	1	1
NBH13	Yeda R.	31.2	30	2	17	17	17	16	1	1	1	1	0
NBH13-2	Yeda R.	20.0	15	1	1	1	1	1	1	1	0	1	0
NBH14	Ambesh R. (Canceled)	-	-	-	-	-	-	-	-	-	-	-	-
NBH15	Ambesh R.	6.5	1	0	0	0	0	0	0	0	0	0	0
NBH16	Chemoga R.	6.9	2	1	1	1	1	1	0	0	0	0	0
NBH17	Chemoga R.	6.6	2	1	1	1	1	1	0	0	0	0	0
NBH18	Abahim R.	18.0	15	1	1	1	1	1	1	0	0	0	0
NBH19	Wiseta R.	8.0	0	0	0	0	0	0	0	0	0	0	1
Total		272.4	202	24	49	49	49	47	9	8	8	12	4

Table 6.5.4 Quantity of test pit and laboratory test

Quantity of sites	Specific Gravity	Moisture Content	Particle Size	Atterberg Limit	Shrinkage Test	CBR Test	Field Density	DCP
40	10	10	50	50	10	10	10	40

Table 6.5.5 Boring and Laboratory Test for Quarry

Site No.	Work on Site	Density and Absorption	Soundness	Los Angeles Abration	Aggregate Crushing Value
AD 2-1	Sampling of Rock	1	1	1	1
AD 4-2	Boring (10m)	1	1	1	1
Q 4	Boring (10m)	1	1	1	1
Q 1	Sampling of Rock	1	1	1	1
AD 6	Sampling of Rock	1	1	1	1
Total		5	5	5	5

Table 6.5.6 Sampling Test Pit and Laboratory Test for Borrow Pit

Site No.	Work on Site	Particle Size (with Hydro)	Atterberg Limit	Linear Shrinkage	CBR (3 points)	Permeability
B 2	Sampling of Soil	2	2	2	2	0
AD 1	Test Pit (H : 5 m)	2	2	2	2	1
AD 2-2	Test Pit (H : 3 m)	1	1	1	1	0
AD 6	Sampling of Soil	2	2	2	2	1
AD 7	Sampling of Soil	3	3	3	3	0
AD 8	Sampling of Soil	1	1	1	1	0
AD 9	Sampling of Soil	1	1	1	1	0
AD 10	Sampling of Soil	2	2	2	2	0
Total		14	14	14	14	2

Table 6.5.7　CBR Test for Mixing Sample with Lime

Former TP No.	New TP No.	Station (km)	Location	Easting	Northing	Lime 2%	Lime 4%	Lime 6%	Total
NTP 2	ETP 1	4+000	Dejen	405312	1128558	2	2	2	6
NTP 13	ETP 2	23+000	Abeya R.	389168	1130038	2	2	2	6
NTP 30	ETP 3	49+000	Yeda R.	371094	1135753	2	2	2	6
Total	-	-	-	-	-	6	6	6	18

4) Outline of Geomorphological and Geological Condition

The geological map of Ethiopia is shown inFigure 6.5.2. Ethiopia is divided into the east part and the west part by the African Great Lift Valley where is a great fault zone from Mozambique, passing though Tanzania and Kenya to Ethiopia being from 30 kilometers to 50 kilometers in width and about 6,000 kilometers in length. Uplift movement of this zone begun mainly at Ethiopia and Kenya in Tertiary. And quantity of uplift movement is between 2,000-3,000 meters in height until today.

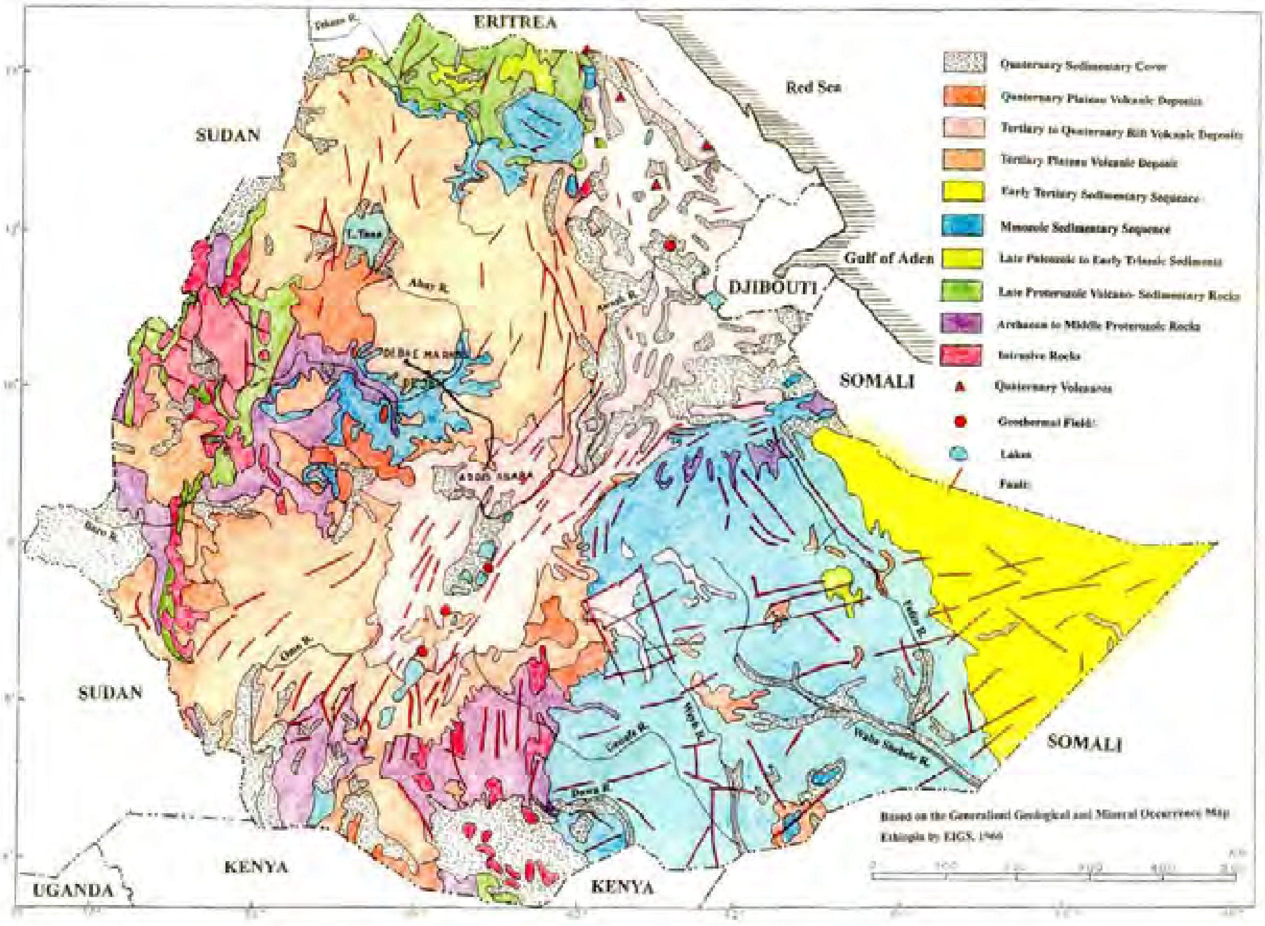


Figure 6.5.2　Geological Map of Ethiopia

As soon as lifting the central part of this lift zone subsided and after that the present fault zone was formed. At the same time, a plenty of basaltic lavas flowed by fissure eruption. And until present time, volcanic activity has continued. There are many active volcanoes in the Lift Valley and small earthquakes sometimes happen. At the central part of the Lift Valley, there are many lakes from the south to the north as a result of subsidence. Flowing basaltic lava in Ethiopia shows the biggest scale at the Lift Valley. So, this activity formed Ethiopian Highland being about 500 kilometers in width and about more than 1.000 kilometers in length. And the height above sea level of Ethiopian Highland is the highest in the Lift valley being between 2.000 meters and 2.500 meters. On the other hand, seismic activity and volcanic activity in Ethiopia are inactive compares with Tanzania and Kenya. In the inner part of Ethiopia Highland, these activities do not happen. The north end of the Lift valley spread out like a fan near Addis Ababa. The eastern end contacts with the Gulf of Aden and the west end continue toward the Red Sea. This triangular zone is called as the Afar Depression. The Afar Depression, crossing three lift valleys, shows complicated geological structure. So, seismic activity and volcanic activity in Ethiopia concentrate on this area.

Basement of Ethiopian Highland consists of marine sedimentary rocks of the Mesozoic Era like a sandstone, mud stone, and limestone.. These sedimentary formations deposit horizontally and are covered with basaltic lava being from 300 meters to 400 meters in thickness in the inside of the Highland. The topography of the Highland is composed by combination of gentle hills and flat plane. These hills being from 50 meters to 150 meters in height are divided into several hill columns by small valley plains being 2 or 3 kilometers in width. On the surface of hills basaltic lavas crop out and they are covered with tropical red soil. On the valley plains, black cotton soils formed by weathering of basalt are distributed as the alluvial soil. Black cotton soil is characterized by a low organic content and by zone of calcium carbonate concretions. In the dry season it forms a black soil which crumbles into dust, or bakes hard if it has not been ploughed. In the wet season it may be plastic or sticky. It is good soil for growing cotton, barley and wheat but is not good for earthworks. The biggest lake in Ethiopia, named Lake Tana (75kilometers in length, 60 kilometers in width and 1830 meters above sea level) in the Highland being 300 kilometers from Addis Ababa toward northwest. The Abay River named Blue Nile River flows from the Lake Tana and joins with the White Nile River in Sudan. After that, this river flows into Egypt as the Nile River. The erosion of the Abay River increased with uplift movement of the Ethiopian plateau. As a result, a big gorge being 1500 meters in height was formed. The Ethiopian Highland gently inclines toward the west. For that reason, almost rivers on the highland gather to the drainage of the Nile River. The project route between Dejen and Debre Marcos being about 63 kilometers in length is located on the plateau of basalt in the west side of the Abay Gorge.

5) Geological Condition along the Route

The route is located in the central part of the Ethiopian volcanic plateau which is slightly tilting to southwest. The altitude of Dejen located on the west bank of the Abay Gorge is about 2500 meters and Debre Marcos apart from 63 kilometers from Dejen is about 2400 meters. The rivers on the plateau flow from north to south cutting valleys, crossing the project route and join the

Abay River. Number of main rivers crossing the route is 13.They are Asametech River, Bechet River, Taba River, Aba Adem River, Bogena River, Getla River, Ziba River, Yeda River, Ambesh River, Chemoga River, Abahim River and Wiseta River from east to west. On the plateau, five columns of hills being from 100 meters to 150 meters in relative height lie along north-south axis. Among the rivers, Abeya River, Getla River, Ziba River and Yeda River have valley plains being 1 ~3 kilometers in width between hills. Especially, Abeya River and Yeda River have wider plains among them. Hills consists of basalt and tuff covered with weathered red soil being 2 ~ 5 meters in thickness. The tops of plateau and surface of valley plains are covered with alluvial brown soil and black cotton soil is found below it. Black cotton soil is thick in the valley plains of Abeya River and Yeda River being about 10 meters and thin in the plateaus being about 2~3 meters . Geological formations distributed on the route are as follows.

.・Upper Brown Clay ~ Silt (UBC)

This formation is mainly distributed on flood plains in valley, partially on the depressions in plateau. This is a soft alluvial deposit being 1 ~3 meters in thickness.

・Upper Red Clay ~ Silt (URC)

This formation is found on the top of hills and slopes, partially as mixing fragment of basalt. Originally, this is formed from weathering of basalt and secondly deposited by action of raining and gravity. This soil is stiff compared with upper brown clay. The thickness is about 2~3 meters on the top of hills and about 5~6 meters on the slopes.

・Black Cotton Soil (BCS)

This formation is found on the plateau and the flood plain in valley. This is a soft silty clay or clayey silt with black or grayish black color. The thickness is about 2 ~ 3 meters on the top of hills. But on the valley plains of Abeya River and Yeda River, it reaches more than 10 meters. This is not distributed on the top of hills but it is found on the slopes below upper red soil. This soil causes swelling in rainy season and shrinking in dry season.

・Lower Clay (LC)

This formation is mainly found below black cotton soil on the valley plains and partially on the depressions of plateau. This is a gray colored hard clay or silt. The thickness is about 12 ~17 meters in Abeya River and Yeda River but only 2 ~ 3 meters on plateaus.

・Residual Soil (RS)

This formation is found below upper red soil on hills. This is a gray or yellowish gray colored hard soil with sometimes gravel or fragment of basalt. And this soil is mainly hard sandy silt or silty sand. The thickness is about 2 ~ 8 meters and sometimes its thickness changes irregularly according to topography..

・Tuff (TF)

This formation is found below upper red soil or residual soil on Aba Adem River and the right bank of Yeda River. This is a yellowish gray or grayish green colored silty soft rock.. On the outcrop, this rock has clear bedding and high hardness. The thickness is estimated about 5 ~20 meters.

・Decomposed Basalt (DBa)

This formation is highly weathered basalt. It looks like a breccia with fragment of basalt and clay. It has enough strength as bearing layer but clay rich zone is unsuitable as bearing layer. The thickness is about 5 ~10 meters.

・Basalt (Ba)

This rock is a basement rock on the route. This is a black or grayish black colored very hard rock. On the outcrop, cracky basalt and porous basalt are found.. But both rocks are no problem bearing layer for foundation of bridge.

6) Result of Standard Penetration Test (SPT)

The result of SPT is shown in Table 6.5.8.

Table 6.5.8 Result of Standard Penetration Test (SPT)

Formation	Number of Times	Max. Value (times/30cm)	Min. Value (times/30cm)	Av. Value (times/30cm)
Upper Brown Soil (UBC)	6	9	1	5
Upper Red Soil (UBC)	6	19	2	13
Black Cotton Soil (BCS)	43	11	2	7
Lower Clay (LC)	80	18	5	12
Residual Soil (RS)	30	50	9	28
Tuff (TF)	5	50	50	50
Decomposed Basalt (DBa)	12	50	25	41
Basalt(Ba)	8	Refuse	50	50

By the table, the upper brown silt (UBC) shows the lowest N value. The upper red silt (URC) shows higher value than the upper brown silt. The upper red silt (URC) which shows N value 2 is an exceptional case by highly weathering. Almost N values of black cotton soil show under 10.The lower clay (LC) is hard clay. So that reason almost N values of it show more than 10 except highly weathered zone. The residual soil (RS) is sandy soil. So it shows very high value compared with other upper formations. The tuff (TF) is soft rock but the N value shows more than 50. The decomposed basalt (DBa) is mixed formation with gravel and clay. The N value of it shows more than 50 but clay rich zone of it shows sometimes under 50.The basalt (Ba) shows rebounding for blow of hummer at the test. This rock is no problem as bearing layer.

7) Result of Measurement of Groundwater Level

Groundwater level in bore holes is shown in Table 6.5.9. At borings of NBH1, NBH2 and NBH6, located on the plateau, the groundwater levels are not confirmed. Here, depth of basement rock is shallow. So that reason groundwater levels are existing under the depth of bore holes as fissure water in rocks. Other borings were drilled on the projected bridge sites at the shoulder of existing road. There, groundwater levels keep balance with river water levels. The filling height of Abeya bridge site is about 1 meter and the groundwater level in bore hole shows same level. At Yeda River, the boring was carried out on natural ground near the bank and the groundwater level in bore hole is very close to river water level. The condition of groundwater level of Ambesh River is as same as Yeda River. On the top of hills, borings were not carried out. There, it seems that the groundwater levels are deep and existing in basalt as fissure water.

Table 6.5.9 Groundwater Level in Bore Hole

B. №	Location	Depth (m)	Date of Measurement
1	Plateau	Nothing	29-Jul-10
2	Plateau	Nothing	30-Jul-10
3	Aba Adem R.	-5.6	31-Jul-10
4	Abeya R.	-1.0	07-Aug-10
5	Abeya R.	-1.0	07-Aug-10
6	Plateau	Nothing	31-Jul-10
7	Bogena R.	-1.8	04-Aug-10
8	Bogena R.	-1.6	05-Aug-10
9	Getla R.	Canceled	—
10	Ziba R.	-6.0	05-Aug-10
11	Yeda R.	-0.9	20-Aug-10
12	Yeda R.	-1.7	14-Aug-10
13	Yeda R.	-1.2	12-Aug-10
13-2	Yeda R.	-1.4	25-Aug-10
14	Ambesh R.	Canceled	—
15	Ambesh R.	-0.1	25-Aug-10
16	Chemoga R.	-1.5	07-Aug-10
17	Chemoga R.	-2.4	08-Aug-10
18	Abahim R.	-3.4	11-Aug-10
19	Wiseta R.	-1.8	12-Aug-10

8) Distribution and Thickness of Black Cotton Soil

The distribution and thickness of black cotton soil is decided by result of field survey, boring, test pit and dynamic cone penetrometer (DCP). The result of test pit and DCP including converted into N value are shown in Table 6.5.10. And the thickness of geological formations is shown inTable 6.5.11. These geological formations change the thickness accompanied with topography. The horizontal continuity of them is shown in geological profiles as Appendix. By the geological profiles, the distribution of black cotton soil is as follows.

- Dejen – Abeya River (plateau and gentle slope), Extension = 21km, Thickness = 2.0~3.0m
- Abeya River (valley plain), Extension = 3km, Thickness = 10.0 ~ 11.0m
- Abeya River – Lumame (valley plain), Extension = 5km, Thickness = 2.0 ~ 3.0m
- Getla River (plateau and gentle slope), Extension = 1km, Thickness = 1.5 ~ 2.0m
- Yeda River (valley plain), Extension = 3km, Thickness = 5.0 ~ 10.0m

The thickest area of black cotton soil is the valley plain of Abeya River and Yeda River. The thickness is about 10m. At the surface of plateau, small valley plain, and foot of slope, black cotton soil is partially found in thickness of about 1.5 ~ 3.0m. Between Yeda River and Debre Marcos, there is wide hilly area without black cotton soil. And at the plateau of Debre Marcos City, black cotton soil is no found.

Table 6.5.10 Depth of Black Cotton Soil in Test Pit between Dejen and Debre Markos

TP No.	Formation	Depth of BCS by TP Logs(m)	Depth of DCP(m) N<10	Depth of BCS by Boring, N<10	Estimated Depth(m)
1	BCS	2.00	3.31		2.5
2	BCS	2.40	2.12		2.5
3	BCS	1.90	1.79	2.50(NBH1)	2.5
4	BCS	2.30	2.55		2.5
5	BCS	2.40	2.84		2.5
6	BCS,LC	3.00	0.00	6.00(NBH2)	3.2
7	URC	2.50	1.13		-
8	BCS	2.50	0.85		2.5
9	BCS	2.40	2.11		2.5
10	BCS	2.40	2.81		2.5
11	BCS	2.40	0.71	3.50(NBH3)	2.5
12	BCS	2.40	2.17	10.00(NBH4.5)	10.0~11.0
13	BCS	3.00	2.65		3.0
14	BCS	2.50	0.00		2.5
15	BCS,LC	3.00	2.32	5.90(NBH6)	3.0
16	BCS	2.70	2.27		2.8
17	BCS	3.00	1.40	3.90(NBH7.8)	3.2
18	BCS	3.00	1.89		3.0
19	URC	3.00	0.53		-
20	URC	3.00	1.50		-
21	URC	2.40	0.00		-
22	BCS	1.40	1.60		1.4
23	BCS	2.70	0.80		2.8
24	URC	2.20	0.00		-
25	URC	3.00	0.00		-
26	URC	1.50	0.57		-
27	URC	2.40	0.00		-
28	URC	2.40	0.00		-
29	BCS	3.00	-	5.50(NBH11)	5.0
30	BCS	2.40	0.55	10.00(NBH12.13)	10.0
31	BCS	2.70	0.72	2.4(NBH13-2)	2.5
32	URC	2.40	0.78		-
33	URC	1.80	1.56		-
34	URC	1.00	0.00		-
35	URC	1.80	1.49		-
36	URC	2.00	0.00		-
37	URC	3.00	0.00		-
38	URC	2.50	0.00		-
39	URC	2.80	1.59		-
40	URC	2.60	0.00		-

Table 6.5.11 Thickness of Soil (Dejen-Debre Markos)

Location	Sta. No.(km)	Thickness of Soil(m)				Total Depth(m)	Basement
		Fill	UpperClay	Black Cotton	Lower Clay		
Dejen	0+000	0.8	0.0	0.0	0.0	0.8	Basalt
	0+450	0.8	0.0	0.0	0.0	0.8	Basalt
	1+600	0.8	0.0	1.5	0.0	2.3	Basalt
	2+200	0.8	0.0	0.0	0.0	0.8	Basalt
	3+200	0.8	0.0	2.0	0.0	2.8	Basalt
	6+200	0.8	0.0	1.7	3.0	5.5	Residual Soil
	6+700	0.8	0.0	1.5	3.0	5.3	Basalt
	8+500	0.0	1.5	2.0	0.0	3.5	Basalt
	10+300	0.5	0.0	2.5	0.0	3.0	Basalt
	10+800	0.5	0.0	1.2	0.5	2.2	Decomposed Basalt
	11+200	0.5	1.0	0.0	0.0	1.5	Decomposed Basalt
Bechet R.	12+400	0.5	0.0	2.5	0.0	3.0	Basalt
	14+300	0.7	0.7	0.0	0.0	1.4	Decomposed Basalt
	18+000	0.8	0.0	1.5	3.0	5.3	Decomposed Basalt
Taba R.	18+300	2.0	0.0	3.0	4.8	9.8	Decomposed Basalt
	19+900	0.5	0.0	2.0	0.0	2.5	Decomposed Basalt
Aba Adem R.	20+200	0.5	0.0	3.0	3.0	6.5	Tuff
	21+300	0.5	0.0	1.5	1.5	3.5	Decomposed Basalt
Abeya R.	22+400	1.0	0.0	10.0	13.0	24.0	Decomposed Basalt
	23+200	0.5	0.0	1.5	0.0	2.0	Decomposed Basalt
	24+200	0.5	1.0	1.0	0.0	2.5	Decomposed Basalt
	25+800	0.5	0.5	0.0	0.0	1.0	Decomposed Basalt
(Marsh)	26+700	0.5	0.0	2.0	3.5	6.0	Basalt
	27+300	0.5	0.5	0.0	0.0	1.0	Basalt
(Marsh)	27+650	0.7	0.0	2.0	0.0	2.7	Basalt
	29+200	0.5	1.0	0.0	0.0	1.5	Decomposed Basalt
Bogena R.	29+700	1.0	0.0	3.0	0.0	4.0	Basalt
Lumame	30+700	0.5	0.0	1.5	0.0	2.0	Basalt
	32+700	0.0	3.0	0.0	0.0	3.0	Basalt
Getla R.	35+630	0.0	3.0	0.0	0.0	3.0	Basalt
	36+900	0.0	3.0	0.0	0.0	3.0	Basalt
	37+900	0.0	0.0	1.5	0.0	1.5	Decomposed Basalt
	38+640	0.0	2.0	0.0	0.0	2.0	Decomposed Basalt
	37+700	0.0	1.0	2.2	0.0	3.2	Decomposed Basalt
	40+260	0.5	3.0	0.0	0.0	3.5	Decomposed Basalt
	41+060	0.0	2.2	0.0	0.0	2.2	Basalt
	42+640	0.5	3.0	0.0	0.0	3.5	Basalt
	42+980	0.0	4.0	0.0	0.0	4.0	Basalt
	43+500	0.0	3.0	0.0	0.0	3.0	Basalt
Ziba R.	44+000	0.9	5.1	0.0	0.0	6.0	Residual Soil
	46+260	0.5	5.0	0.0	0.0	5.5	Residual Soil
	46+880	0.0	3.0	0.0	0.0	3.0	Basalt
Yeda R.	48+420	0.0	0.0	5.5	13.5	19.0	Decomposed Basalt
Yeda R.	49+500	0.0	2.0	8.0	18.0	28.0	Basalt
Yeda R.	49+800	0.0	2.0	4.0	14.0	20.0	Basalt
	50+140	0.0	2.0	1.0	1.0	4.0	Residual Soil
	50+340	0.0	2.0	2.0	0.0	4.0	Residual Soil
	50+660	0.0	1.5	1.0	0.0	2.5	Residual Soil
	51+420	0.0	1.5	0.0	0.0	1.5	Residual Soil
	55+020	0.0	2.0	0.0	0.0	2.0	Basalt
	57+100	0.0	1.5	0.0	0.0	1.5	Basalt
	60+820	0.5	3.0	0.0	0.0	3.5	Basalt
Abahim R.	60+920	4.0	5.5	0.0	6.0	15.5	Residual Soil
Debre M.	64+880	0.0	3.0	0.0	0.0	3.0	Decomposed Basalt

9) **Geological Condition in the Projected Bridge Site**

・Aba Adem River Site (Boring NBH3)

Aba Adem River is a small river flowing on the plateau. On the both banks of it, black cotton soil (BCS) being 3.5m in thickness lower clay (LC) is found below BCS. .At the bottom of boring, tuff (TF) as basement rock is found at 6.1m in depth. N value of tuff shows more than 50 and it is no problem for foundation of bridge.

・Abeya River Site (Boring NBH4 and NBH5)

Abeya River has a valley plain being 2 ~ 3 km in width. The left bank consists of tuff, decomposed basalt (DBa) and fresh basalt (Ba). And the right bank and the bottom of plain consist of decomposed basalt (DBa). N values of these rocks show more than 50 and they have enough strength for foundation of bridge. The valley plain is filled with Quaternary deposits being 23m in thickness. They consist of black cotton soil (BCS) being 10 ~ 11m in thickness and lower hard clay (LC) being 12 ~ 13m in thickness. The N value of black cotton soil (BCS) shows 10 under. So this soil has a possibility of consolidation settlement by filling work.

・Bogena River Site (Boring NBH7 and NBH8)

Bogena River has a valley plain being about 1 km in width. In the valley plain, black cotton soil (BCS) being 3.9m in thickness is found. And fresh hard basalt (Ba) is found below BCS. This rock is no problem for foundation of bridge.

・Getra River Site (Boring NBH9 was cancelled. Test Pit. NTP41 and DCP were carried.)

This site is located in the upper stream separated from existing road with a distant of 1.7km. Boring NBH9 was cancelled because of bad accessibility to the site. So test pit and dynamic cone penetrometer(DCP) were carried out instead of boring. By the result, the both banks consist of upper red silt (URC) being 3m in thickness. And decomposed basalt (DBa) is found below it. N value of DBa shows more than 50 but it is highly weathered rock. So it is desirable to get more fresh rock for foundation of bridge. It seems that fresh rock shall be gotten to drill at least 2 ~ 3 m more.

・Ziba River Site (Boring NBH10)

This site is located on the slope of hill. The surface of hill is covered with upper red silt (URC) being 6 m in thickness. N value of URC shows more than 10. Residual soil (RS) is found below URC. N value of RS shows 10 under. Fresh basalt (Ba) is found in depth of 9.2 m below RS in the bottom of bore hole. This rock has enough strength for foundation of bridge.

・Yeda River Site (Boring NBH11, NBH12, NBH13 and NBH 13-2)

Yeda River has a valley plain being about 3 km in width. The left bank consist of decomposed basalt (DBa) and fresh basalt (Ba). And right bank consists of residual soil (RS) and hard tuff (TF).

They are covered with upper red soil (URC) being 2 ~ 4 m in thickness. And on the slope of hills, black cotton soil (BCS) being 2 ~ 5 m in thickness is found below URC. The valley plain is filled with thick Quaternary deposits. They are as follows from upper to lower.

- Upper brown silt (UBC), (thickness = 2 ~ 3 m, N value = 10 under)

- Black cotton soil (BCS), (thickness = 10 m, N value = 10 under)

- Lower clay (LC), (thickness = 16 ~ 18 m, N value = 10 ~ 15)

And decomposed basalt (DBa) is found as basement rock in depth of 27 ~ 28 m. Among those formation, UBC and BCS have a possibility of consolidation settlement by filling work.

・Ambesh River Site (Boring NBH15)

Ambesh River is a small river crossing hilly area .and has no valley plain. The both banks consist of fresh basalt (Ba) covered with upper red silt (URC) being 2 m in thickness. The basalt is no problem for foundation of bridge.

・Chemoga River (Boring NBH16 and NBH17)

Chemog River is running between erosional terrace being about 200 ~ 300 m in width. On the both banks, terrace surfaces are covered with upper red silt (URC) being 3.0 ~ 3.7 m in thickness. And fresh basalt (Ba) is found below URC as basement rock. This rock is no problem for foundation of bridge.

・Abahim River Site (Boring NBH18)

Abahim River is located in the east side of Debre Marcos City on the plateau. The existing road is crossing this river with filling and bridge being 4 m in height. Below the filling materials, upper red silt (URC) being 5 m in thickness and gravelly residual soil (RS) being 6 m in thickness are found. And decomposed basalt (DBa) is found in depth of 15.5 m. N value of DBa shows more than 50. This basalt is no problem for foundation of bridge.

・Wiseta River Site (Boring NBH18 in Bypass Road)

Wiseta River is running on east edge of Debre Marcos City. The both banks consist of decomposed basalt (DBa) and fresh basalt (Ba). And they are covered with upper red silt (URC) being 1.7 m in thickness. Although weathered rock, DBa is very hard showing N value more than 50. This rock is no problem for foundation of bridge.

・Wiseta River Site (Boring BH19-2003 in Main Road)

This site is located on the existing national highway No.3. The boring of this site was carried out at November, 2003 during the former project. The both banks consist of decomposed basalt (DBa) and fresh basalt (Ba). And they are covered with upper red silt (URC) being 4 m in thickness. The N value of DBa shows between 33 and 50. So it is desirable to select fresh basalt being 6 m in depth as foundation of bridge.

10) **Result of Laboratory Test**

Laboratory test was carried out for undisturbed and disturbed samples by borings and test pits. The result is shown in Table 6.5.12 for undisturbed samples, Table 6.5.13 for disturbed samples and Table 6.5.14, Table 6.5.15, Table 6.5.16 for test pit samples. Main symbols used in the Tables are as follows.

- LL (%) Liquid Limit
- PL (%) Plastic Limit
- PI Plasticity Index
- SL (%) Shrinkage Limit
- OMC (%) Optimum Moisture Content
- MDD (g / cm^3) Maximum Dry Density
- USCS Unified Soil Classification System

Table 6.5.12 Summary of Lab. Results for Undisturbed Samples

Sr. No	Investigation Site	BH No.	Field Material Description	Depth Sampled (m)	% pass (mm) 2.000	0.425	0.075	LL %	PL %	PI %	AASHTO Soil Class	USCS	Hydrometer Analysis Sand% (2.0-0.06mm)	Silt% (0.06-0.02mm)	Clay% (<0.002 mm)	NMC, %	Sp.Gravity	S.L %	Unit Weight	UCS, KPa	Triaxial (UU) C, KPa	?	Consolidation Parameters e_o	e_f	C_c
1	Black cotton soil area	NBH1	Dark, soft silty CLAY	2.00-2.50	100	100	99	115	38	77	A-7-5 (20)	CH	23.10	59.51	17.39	41.5	2.733	3.23	1.855	69	-	-	1.0573	0.82	0.389
2			Yellowish gray, stiff silty CLAY	5.40-5.75	100	99	97	102	40	62	A-7-5 (20)	CH	25.03	52.92	22.05	34.0	2.717	-	1.397	-	-	-	-	-	-
3	Black cotton soil area	NBH2	Gray,soft silty CLAY	2.00-2.50	100	99	98	107	35	72	A-7-5 (20)	CH	13.73	67.85	18.42	40.0	2.675	2.83	1.664	231	37	12°	-	-	-
4			Gray, soft silty CLAY	2.50-300	100	99	98	105	40	65	A-7-5 (20)	CH	9.80	67.78	22.42	38.0	2.630	-	1.764	-	-	-	0.8858	0.8487	0.11
5	Abadem R.(Right Bank)	NBH3	Dark, soft silty CLAY	2.00-2.50	98	95	94	102	32	70	A-7-5 (20)	CH	11.49	66.18	20.23	38.0	2.270	1.87	1.727	-	-	-	1.193	1.1005	0.07
6			Dark, soft silty CLAY	2.50-3.00	100	100	98	116	47	69	A-7-5 (20)	CH	21.95	61.39	16.66	45.0	2.736	4.40	1.613	-	42	16°	-	-	-
7	Abeya R.(Left Bank)	NBH4	Dark, soft silty CLAY	2.00-250	100	100	99	98	47	51	A-7-5 (20)	MH	12.08	65.34	22.57	37.8	2.625	3.84	1.785	-	-	-	0.9764	0.7284	0.482
8			Dark, soft silty CLAY	2.50-3.00	100	100	99	99	37	62	A-7-5 (20)	CH	6.44	76.78	16.77	34.7	2.715	7.26	1.635	-	38	12°	-	-	-
9	Abeya R.(Right Bank)	NBH5	Dark, soft silty CLAY	3.00-3.50	100	100	99	90	37	53	A-7-5 (20)	CH	29.14	48.31	22.55	44.0	2.698	-	1.223	-	-	-	-	-	-
10	Plateau	NBH6	Gray, soft silty CLAY	2.50-300	100	99	97	96	44	52	A-7-5 (20)	MH	12.44	64.46	23.11	40.1	2.652	6.17	1.725	13	-	-	1.0992	0.7495	0.575
11	Bogena R.(Left Bank)	NBH7	Dark, very soft Gravley Sandy Silty CLAY	3.00-3.50	100	93	87	80	37	43	A-7-5 (20)	MH	18.67	57.91	22.94	31.0	2.865	-	1.463	-	-	-	-	-	-
12	Bogena R.(Right Bank)	NBH8	Dark, very soft silty CLAY	2.50-3.00	100	99	98	116	46	70	A-7-5 (20)	CH	25.52	53.79	20.69	61.0	2.747	-	1.124	-	-	-	-	-	-
13	Ziba R.(Right Bank)Near the river	NBH10	Reddish brown, firm silty CLAY	2.00-2.40	100	100	99	52	31	21	A-7-5 (15)	MH	10.45	63.63	25.92	35.3	2.660	15.06	1.671	-	-	-	1.0654	0.958	0.216
14			Reddish brown, firm silty CLAY	2.40-2.80	100	100	99	63	38	25	A-7-5 (18)	MH	24.45	59.42	16.13	31.0	2.760	-	1.612	308	45	17°	-	-	-
15	Yeda R.(Left Bank)	NBH11	Dark gray,very soft silty CLAY	2.50-3.00	100	97	96	94	37	57	A-7-5 (20)	CH	18.10	56.16	25.74	42.3	2.627	6.79	1.782	44	28	14°	-	-	-
16	Yeda R.(Left Bank)	NBH12	Dark gray, soft silty CLAY	2.00-2.50	100	100	100	80	40	40	A-7-5 (20)	MH	24.55	45.27	30.18	43.1	2.712	7.75	1.727	35	-	-	0.907	0.63	0.233
17			Dark gray, soft silty CLAY	2.50-3.00	100	100	99	82	41	41	A-7-5 (20)	MH	11.10	62.75	26.15	43.5	2.609	-	1.694	-	36	15°	-	-	-
18	Yeda R.(Left Bank) Near the river	NBH13	Dark brown, very soft Sandy Silty CLAY	2.00-2.50	100	98	92	61	34	27	A-7-5 (19)	MH	18.55	52.84	28.61	30.5	2.804	10.73	1.685	104	-	-	0.907	0.56	0.258
19			Dark brown, very soft silty CLAY	2.50-3.00	100	100	99	68	36	32	A-7-5 (20)	MH	31.55	51.99	16.46	49.3	2.728	-	1.667	-	12	7°	-	-	-
20	Yeda R.	NBH13-2	Brownish to dark gray silty, firm CLAY/SAND	2.00-2.50	100	97	95	94	40	54	A-7-5 (20)	MH	12.49	63.33	24.18	21.3	2.698	2.45	1.694	51	38	10°	-	-	-
21	Chemoga R.(Left Bank)	NBH16	Light brown, soft silty CLAY	2.00-2.50	100	97	96	70	39	31	A-7-5 (20)	MH	32.45	40.53	27.02	45.0	2.793	-	1.143	-	-	-	-	-	-
22	Chemoga R.(Right Bank)	NBH17	Gray, soft Sandy Silty CLAY	2.50-3.00	95	84	83	77	37	40	A-7-5 (20)	MH	16.01	56.95	22.08	35.0	2.836	-	1.410	-	-	-	-	-	-
23	Abahim R.(Left Bank)	NBH18	Dark brown, soft silty CLAY	5.00-5.50	99	97	95	53	32	21	A-7-5 (15)	MH	14.73	60.80	23.51	45.0	2.652	-	1.697	32	-	-	-	-	-

Table 6.5.13 Summary of Lab. Result for Disturbed (SPT) Samples

Sr. No	BH No.	Field Material Description	Depth (cm)	% pass (mm)			LL %	PL %	PI %	AASHTO Soil Class	USCS	Hydrometer Analysis			NMC	Sp.Gravity
				2.000	0.425	0.075						Sand % (2.0-0.06mm)	Silt % (0.06-0.02mm)	Clay % (<0.002 mm)		
1	NBH-4 (Abeya River)	Dark,very soft gravely silty CLAY	4.00-4.45	99	99	98	110	50	60	A-7-5 (20)	MH	5.44	68.54	25.25	46.0	2.606
2		Dark, soft silty CLAY	6.00-6.45	100	99	99	101	39	62	A-7-5 (20)	CH	13.48	58.16	27.82	50.0	2.660
3		Dark, soft silty CLAY	8.10-8.55	100	99	98	99	39	60	A-7-5 (20)	CH	14.76	58.45	26.79	50.0	2.715
4		Dark gray , firm silty CLAY	10.00-10.45	98	97	96	104	56	48	A-7-5 (20)	MH	6.91	65.31	26.13	48.0	2.660
5		Dark gray, soft sandy gravely silty CLAY	12.10-12.55	100	88	87	103	43	60	A-7-5 (20)	MH	6.71	58.83	25.58	53.0	2.701
6		Gray, firm silty CLAY	14.10-14.55	100	99	98	102	41	61	A-7-5 (20)	CH	11.12	63.66	24.96	41.0	2.728
7		Gray, firm silty CLAY	16.00-16.45	100	99	99	96	43	53	A-7-5 (20)	MH	9.63	65.61	24.76	46.0	2.641
8		Brownish gray, firm silty CLAY	18.00-18.45	100	100	94	82	36	46	A-7-5 (20)	MH	11.71	64.74	23.54	49.0	2.665
9		Brownish gray, firm silty CLAY	20.00-20.45	100	100	98	112	51	61	A-7-5 (20)	MH	9.94	63.57	26.49	48.0	2.624
10		Brownish gray, firm silty CLAY	22.00-22.45	100	99	98	110	41	69	A-7-5 (20)	CH	20.61	53.78	25.61	52.0	2.702
11		Gray to yellowish gray ,sandy silty CLAY	24.00-24.45	100	100	93	94	54	40	A-7-5 (20)	MH	17.68	52.92	29.40	57.0	2.702
12	NBH13 (Yeda River)	Very soft, dark brown silty CLAY	1.00-1.45	100	100	97	51	32	19	A-7-5 (14)	MH	26.99	50.20	22.82	30.0	2.741
13		Very soft,dark silty CLAY	4.00-4.45	100	100	99	92	48	44	A-7-5 (20)	MH	11.23	62.66	26.11	63.0	2.616
14		Very soft,dark silty CLAY	6.00-6.45	100	99	99	101	47	54	A-7-5 (20)	MH	15.07	58.91	25.61	54.0	2.682
15		Very soft,dark silty CLAY	8.00-8.45	98	96	94	103	45	58	A-7-5 (20)	MH	10.18	60.08	27.94	69.0	2.740
16		Firm, dark gray silty CLAY	10.00-10.45	100	99	97	84	41	43	A-7-5 (20)	MH	15.55	57.71	26.74	43.0	2.628
17		Firm, dark gray silty CLAY	12.00-12.45	100	99	98	79	38	41	A-7-5 (20)	MH	15.83	57.02	27.15	45.0	2.740
18		Stiff,dark gray silty CLAY	14.00-14.45	100	99	97	62	40	22	A-7-5 (17)	MH	11.13	66.33	22.11	47.0	2.603
19		Firm, dark gray silty CLAY	16.00-16.45	97	95	93	92	36	56	A-7-5 (20)	CH	7.56	68.40	20.63	45.0	2.719
20		Firm, dark gray silty CLAY	18.00-18.45	100	100	99	106	46	60	A-7-5 (20)	MH	14.82	57.70	27.48	51.0	2.610
21		Firm, dark gray silty CLAY	20.00-20.45	100	100	99	96	44	52	A-7-5 (20)	MH	12.90	57.16	29.94	51.0	2.728
22		Dark gray and yellowish brown,firm silty CLAY	22.00-22.45	100	100	99	90	36	54	A-7-5 (20)	CH	8.23	64.00	27.77	49.0	2.755
23		Dark gray and yellowish brown,firm silty CLAY	24.00-24.45	100	99	99	93	46	47	A-7-5 (20)	MH	7.35	67.85	24.79	45.0	2.618
24		Dark gray, firm silty CLAY	26.00-26.45	100	100	100	106	50	56	A-7-5 (20)	MH	13.61	57.59	28.80	55.0	2.605
25		Dark gray, firm silty CLAY	28.00-28.45	98	97	96	101	44	57	A-7-5 (20)	MH	18.56	56.65	22.66	30.0	2.601
26		Dark gray,decomposed basalt (Clayey sandy GRAVEL)	30.00-30.45	63	54	38	54	45	9	A-5 (1)	MH	26.37	18.06	18.06	34.0	2.694

Table 6.5.14 Summary of Lab. Result for Test Pit Sample(1)

Sr. No	Station (km)	Field Material Description	Test Pit No.	Depth (cm)	% pass (mm) 2.000	% pass (mm) 0.425	% pass (mm) 0.075	LL %	PL %	PI %	AASHTO Soil Class	Hydrometer Analysis Sand% (2.0-0.06mm)	Hydrometer Analysis Silt% (0.06-0.02mm)	Hydrometer Analysis Clay% (<0.002 mm)	Sp.Gravity	Vol. Shrinkage	OMC %	MDD T-180 g/cm³	3 - Point CBR% 10 blows Density g/cm3	10 blows CBR	10 blows Swell %	30 blows Density g/cm3	30 blows CBR	30 blows Swell %	65 blows Density g/cm3	65 blows CBR	65 blows Swell %	NMC
1	1 + 500	Dark to dark gray silty CLAY with little Gravels	NTP 1	80-200	65	62	55	69	31	38	A-7-5 (14)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	4 + 000	Dark silty CLAY	NTP 2	60-240	100	100	98	89	38	51	A-7-5 (20)	10.10	61.30	28.60	2.603	11	24.0	1.490	1.220	1	11.43	1.387	1	11.04	1.501	2	9.96	38.0
3	5 + 500	Dark silty CLAY	NTP3	45-300	98	94	88	87	41	46	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4		Light gray silty CLAY		190-270	100	100	98	109	36	73	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	7 + 500	Brownish silty CLAY	NTP 4	0-70	100	99	94	83	43	40	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6		Dark to dark gray silty CLAY		70-300	96	83	80	87	43	44	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	9 + 500	Dark to dark gray silty CLAY	NTP 5	110-240	100	97	95	85	41	44	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	11 + 500	Dark silty CLAY	NTP 6	50-250	100	100	98	117	44	73	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	13 + 500	Decomposed basait GRAVEL	NTP 7	135-200	67	54	46	80	38	42	A-7-5 (10)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	13 + 500	Dark silty CLAY	NTP7	70-135	92	88	86	80	38	42	A-7-5 (20)	13.50	59.41	19.39	2.651	8	17.0	1.510	1.266	1	9.13	1.450	1	8.60	1.526	2	7.95	38.0
11	15 + 500	Dark silty CLAY	NTP 8	55-210	98	95	92	105	43	62	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	16 + 500	Dark silty CLAY	NTP 9	85-240	100	98	96	122	49	73	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	17 + 500	Dark silty CLAY	NTP 10	60-130	100	98	95	98	44	54	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14		Dark gray silty CLAY		130-240	100	100	99	121	47	74	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	19 + 500	Dark silty CLAY	NTP11	50-130	100	98	90	89	42	47	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16		Dark gray silty CLAY		130-140	100	99	92	81	53	28	A-7-5 (19)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	21 + 500	Dark silty CLAY	NTP12	110-210	99	98	96	104	53	51	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	23 + 000	Dark silty CLAY	NTP13	55-300	100	97	94	86	35	51	A-7-5 (20)	11.10	61.54	27.36	2.784	6	26.5	1.561	1.166	1	8.80	1.397	2	8.66	1.497	2	8.38	33.0

Table 6.5.15 Summary of Lab. Result for Test Pit Sample(2)

Sr. No	Station (km)	Field Material Description	Test Pit No.	Depth (cm)	% pass (mm)			LL %	PL %	PI %	AASHTO Soil Class	Hydrometer Analysis			Sp.Gravity	Vol. Shrinkage	OMC %	MDD T-180	3 - Point CBR %									NMC
					2.000	0.425	0.075					Sand% (2.0-0.06mm)	Silt% (0.06-0.02mm)	Clay% (<0.002 mm)				g/cm³	10 blows Density g/cm3	10 blows CBR	10 blows Swell %	30 blows Density g/cm3	30 blows CBR	30 blows Swell %	65 blows Density g/cm3	65 blows CBR	65 blows Swell %	
19	24 + 000	Brown to dark brown silty CLAY	NTP14	50-160	97	92	83	74	40	34	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20		Dark silty CLAY		160-250	96	83	80	95	38	57	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	26 + 500	Dark gray silty CLAY	NTP15	75-300	94	91	89	86	43	43	A-7-5 (20)	17.72	58.08	18.50	2.645	9	20.0	1.530	1.238	1	13.34	1.423	2	13.20	1.522	2	12.37	53.0
22	27 + 500	Dark silty CLAY	NTP 16	70-270	97	92	87	112	41	71	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	29 + 000	Dark silty CLAY	NTP17	50-250	97	92	87	75	38	37	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24		Dark gray silty CLAY		250-300	100	97	95	102	39	63	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	30 + 000	Dark silty CLAY	NTP 18	110-300	100	100	99	102	43	59	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	32 + 000	Reddish brown latteritic silty CLAY	NTP19	0-250	100	100	98	79	36	43	A-7-5 (20)	23.65	48.35	28.00	2.759	14	26.3	1.450	1.106	1	4.04	1.347	3	2.78	1.429	9	0.99	35.0
27	34 + 500	Dark to dark brown silty CLAY	NTP 20	0-300	100	99	97	88	42	46	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	36 + 000	Dark silty CLAY	NTP 21	0-130	100	94	91	87	41	46	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29		Light brown silty CLAY with decoposed basaltic Gravel		130-250	92	83	77	89	39	50	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	37 + 500	Dark silty CLAY	NTP 22	0-140	98	94	91	93	41	52	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31		Light brown silty CLAY mixed with decoposed basaltic Gravel		140-270	88	82	79	90	36	54	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32	38 + 500	Dark silty CLAY	NTP 23	50-270	97	93	92	78	46	32	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
33	40 + 500	Reddish brown latteritic silty CLAY	NTP 24	0-220	100	99	97	63	37	26	A-7-5 (18)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
34	42 + 500	Reddish brown latteritic silty CLAY	NTP25	70-300	100	99	97	62	34	28	A-7-5 (20)	11.00	62.38	26.17	2.732	17	21.7	1.483	1.114	1	3.24	1.373	4	2.59	1.473	9	1.15	31.0
35	43 + 500	Basaltic GRAVEL mixed with light brown silty CLAY	NTP 26	0-150	95	94	90	62	37	25	A-7-5 (18)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36	45 + 000	Light brown silty CLAY	NTP 27	50-250	100	100	97	63	39	24	A-7-5 (18)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37	46 + 500	Dark brown silty CLAY with little Gravel	NTP 28	60-250	99	96	91	84	44	40	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	48 + 000	Dark silty CLAY	NTP 29	0-300	98	95	94	106	48	58	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39	49 + 500	Alluvial dark silty CLAY with fine bunds of reddish silty CLAY	NTP30	0-240	100	99	98	100	57	43	A-7-5 (20)	9.80	61.58	28.62	2.783	14	29.0	1.385	1.126	2	9.88	1.324	2	8.39	1.393	2	7.85	36.0

Table 6.5.16 Summary of Lab. Result for Test Pit Sample(3)

Sr. No	Station (km)	Field Material Description	Test Pit No.	Depth (cm)	% pass (mm) 2.000	% pass (mm) 0.425	% pass (mm) 0.075	LL %	PL %	PI %	AASHTO Soil Class	Hydrometer Analysis Sand% (2.0-0.06mm)	Hydrometer Analysis Silt% (0.06-0.02mm)	Hydrometer Analysis Clay% (<0.002 mm)	Sp.Gravity	Vol. Shrinkage	OMC %	MDD T-180 g/cm³	3 - Point CBR % 10 blows Density g/cm3	10 blows CBR	10 blows Swell %	30 blows Density g/cm3	30 blows CBR	30 blows Swell %	65 blows Density g/cm3	65 blows CBR	65 blows Swell %	NMC
40	50 + 500	Dark silty CLAY	NTP31	0-270	99	94	90	86	42	44	A-7-5 (20)	16.35	56.55	26.23	2.802	13	24.0	1.463	1.159	1	8.85	1.370	2	7.33	1.474	2	6.39	46.0
41	51 + 500	Light brown latteritic silty CLAY	NTP 32	0-240	100	100	98	70	33	37	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
42	53 + 000	Light brown latteritic silty CLAY	NTP 33	0-180	100	97	93	63	41	22	A-7-5 (17)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
43	55 + 000	Reddish brown latteritic silty CLAY	NTP 34	60-100	97	96	94	81	43	38	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
44	56 + 500	Light brown silty CLAY	NTP 35	80-180	97	87	85	76	45	31	A-7-5 (20)	19.4	53.89	24.01	2.771	14	23.5	1.542	1.234	2	6.55	1.453	3	5.34	1.527	4	3.79	41.0
45	57 + 500	Reddish brown latteritic silty CLAY	NTP 36	45-200	100	99	98	71	39	32	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46	59 + 000	Reddish latteritic silty CLAY	NTP 37	50-300	92	90	89	80	44	36	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
47	60 + 500	Reddish latteritic silty CLAY	NTP 38	40-250	100	100	95	59	36	23	A-7-5 (17)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48	62 + 000	Reddish brown latteritic silty CLAY	NTP 39	0-180	98	93	89	64	33	31	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
49		Reddish brown latteritic silty CLAY		180-280	98	97	95	65	34	31	A-7-5 (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50	63 + 000	Reddish brown latteritic silty CLAY	NTP40	0-260	100	100	98	74	44	30	A-7-5 (20)	10.1	60.16	29.44	2.753	17	27.0	1.464	1.154	2	3.86	1.342	6	2.84	1.383	11	2.07	43.0

・Shrinkage Test

Shrinkage limited is gotten by shrinkage test. Shrinkage limit shows moisture content when property of soil changes from plastic state to solid state. By the test result, shrinkage limit (SL) and shrinkage ratio(R) of black cotton soil and upper red soil are as follows.

Table 6.5.17 **Shrinkage limit (SL) and Shrinkage ratio(R)**

Formation	SL (%)	R	Average SL (%)	Average R
Black Cotton Soil (BCS)	3.2~12.5	2.0~2.2	6.7	2.1
Upper Red Soil(URC)	14.1~16.8	1.9~2.0	15.7	1.9

Between black cotton soil and upper red soil, average of shrinkage limit of upper red soil shows more than twice value compared with black cotton soil. This means that black cotton soil is clayey and its void ratio is large. On the other hand upper red soil is silty and its void ratio is small. Expansiveness of soil is calculated from shrinkage limit. It is very important factor for earthwork. By the Field Survey Manual of Ethiopia (ERA, 2002) and the Tanzanian Highway Design Manual(1999), the expansiveness of soil is calculated by next formula.

Eex = 2.4Wpm－3.9Ws + 32.5

Eex = Expansiveness

Wp(%) = PI(Passing through 0.425mm sieve) / 100

Ws(%) = SL(Passing through 0.425mm sieve) / 100

These values are divided into 3 types based on the manuals mentioned above. This classification is utilized for check of quality of soil.

Table 6.5.18 **Expansiveness**

Expansiveness	Classification
< 20	Low
20 - 50	Medium
>50	High

The expansiveness of each formation is shown in the next table.

Table 6.5.19 **Result of Expansiveness Calculation**

Km	Layer	Passing 0.425mm	LL (%)	PL (%)	PI	SL (%)	Wp (%)	Ws (%)	Eex
4+000	BCS	99	89	38	51	11	50.5	10.9	111
13+500	BCS	92	80	38	42	8	38.6	7.4	97
23+000	BCS	96	86	35	51	6	49.0	5.8	128
26+500	BCS	85	86	43	43	9	36.6	7.7	90
32+000	URC	100	79	36	43	14	43.0	14.0	81
42+500	URC	99	62	34	28	17	27.7	16.8	33
49+500	UBC	100	100	57	43	14	43.0	14.0	81
50+500	BCS	95	86	42	44	13	41.8	12.4	85
56+500	UBC	86	76	45	31	14	26.7	12.0	50
63+000	URC	99	74	44	30	17	29.7	16.8	38

By the test result, expansiveness of all black cotton soil shows more than 85. It is classified into [high]. On the other hand, expansiveness of red silt shows between 33 and 81. It is classified into between [high] and [medium].

・Unconfined Compression Test

Unconfined compression test was carried out for 9 samples. The result is as follows.

Table 6.5.20 Compression Strength

BH No.	Layer	Compression Strength, qu (Kpa)
NBH1	BCS	69
NBH2	LC	231
NBH6	BCS	13
NBH10	URC	308
NBH11	BCS	44
NBH12	BCS	35
NBH13	UBC	104
NBH13-2	UBC	51
NBH18	UBC	32

BCS = black cotton soil, LC = Lower Clay, URC = upper red silt, UBC = upper brown silt

By the test result, qu value of lower clay (LC) and upper red silt (URC) show high values being 231(kpa) and 308 (kpa). These 2 samples are hard clay ~ silt with high N values being 10 ~ 15. On the other hand, qu values of black cotton soil (BCS) show very low values between 13 (kpa) and 69 (kpa).

・Tri-axial Compression Test (UU)

Tri-axial compression test was carried out for 8 samples. The result is as follows.

Table 6.5.21 Tri-axial Compression Test

BH No.	Layer	Cohesion, C (kpa)	Angle of Internal Friction, ϕ (°)
NBH2	BCS	37	12
NBH3	BCS	42	16
NBH4	BCS	38	12
NBH10	URC	45	17
NBH11	BCS	28	14
NBH12	BCS	36	15
NBH13	UBC	12	7
NBH13-2	UBC	38	10

BCS = black cotton soil, URC = upper red silt, UBC = upper brown silt

By the test result, upper red silt (URC) shows maximum value for cohesion and angle of internal friction among all samples. The cohesions of black cotton soil show between 36 (kpa) and 42 (kpa). And the angles of internal friction show between 12 and 16 ° .

・Consolidation Test

Analysis of consolidation settlement was carried out for 3 sites of black cotton soil sections on the plateau near Dejen , valley plains in Abeya River and in Yeda River. The calculation is based on the Δe method. And next 4 cases of calculation were carried out corresponding to projected height of fillings. The calculation is as follows.

Table 6.5.22　Case 1, Dejen (NBH2)

Height of fill, H = 1m	Fill, γ t = 19.0 KN/m3	e 0= 0.8858
Width of top, Wt= 11m	Settlement layer, γ t = 17.6 KN/m3	e f= 0.8487
Width of bottom, Wb= 15m	Thickness of layer, t= 5.0m	Cc = 0.07
Slope of fill = 1:2	Ground water level = Nothing	

Table 6.5.23　Case 2, Dejen (NBH2)

Height of fill, H = 3m	Fill, γ t = 19.0 KN/m3	e 0 = 0.8858
Width of top, Wt = 11m	Settlement layer, γ t = 17.6 KN/m3	e f = 0.7284
Width of bottom, Wb = 23m	Thickness of layer, t = 5.0 m	Cc = 0.07
Slope of fill = 1:2	Groundwater level = Nothing	

Table 6.5.24　Case 3, Abeya River (NBH4)

Height of fill, H = 5 m	Fill, γ t = 19.0 KN/m3	e 0 = 0.9764
Width of top, Wt = 11 m	Settlement layer, γ t = 17.9 KN/m3	e f = 0.7284
Width of bottom, Wb = 31m	Thickness of layer, T = 10.0m	Cc = 0.482
Slope of fill = 1:2	Groundwater level = -1.0m	

Table 6.5.25　Case 4, Yeda River (NBH13)

Height of fill, H = 5m	Fill, γ t = 19.0 KN/m3	e 0 = 0.907
Width of top, Wt = 11m	Settlement layer, γ t = 16.9 KN/m3	e f = 0.560
Width of bottom, Wb = 31m	Thickness of layer, t = 10.0m	Cc = 0.258
Slope of fill = 1:2	Groundwater level = -1.2m	

The result of calculation for quantity of settlement and the time for settlement are as follows.

Table 6.5.26　Result of calculation

Location	Dejen (NBH2)	Dejen ((NBH2)	Abeya (NBH4)	Yeda (NBH13)
Height of fill	H = 1m	H = 3m	H = 5m	H = 5m
Quantity	0.028 cm	0.067 cm	4.2 cm	25.1 cm
Time (90%)	490 months	494 months	903 months	119 months

The quantity of settlement of Yeda River shows maximum value. .Because Yeda River often floods in rainy season and flooding time is longer compared with Abeya River. So that reason, the sediments of valley plain shows very low N value by weathering.

・CBR Test

CBR test was carried out for 10 samples selected among 44 test pits . The test result is as follow.

Table 6.5.27 Result of CBR Test

TP No.	Layer	OMC (%)	MDD (g/cm3)	CBR (65 blows)	Swell (%)
NTP2	BCS	24.0	1.490	2	9.96
NTP7	BCS	17.0	1.510	2	7.95
NTP13	BCS	26.5	1.561	2	8.38
NTP15	BCS	20.0	1.530	2	12.37
NTP19	URC	26.3	1.450	9	0.99
NTP25	URC	21.7	1.483	9	1.15
NTP30	UBC	29.0	1.385	2	7.85
NTP31	BCS	24.0	1.463	2	6.39
NTP35	URC	23.5	1.542	4	3.79
NTP40	URC	27.0	1.464	11	2.07

BCS = black cotton soil, URC = upper red silt, UBC = upper brown silt

By the test result, CBR values of black cotton soil (BCS) show only 2. On the other hand, values of upper red silt (URC) show between 4 and 11. Swelling test is carried out to check the volume change of compacted sample after soaking. By the result of this test, swell value of black cotton soil (BCS) show between 6.39 and 12.37. On the other hand, values of upper red silt (URC) show between 0.99 and 3.79.By the standard of Japan Society of Soil Mechanics and Foundation Engineering, the swell is classified according to the values. It is as follows.

Table 6.5.28 Swell

Condition of Subgrade	Swell (%)
Good Subgrade	1 under
Normal Subgrade	3 under
Bad Subgrade	3 over
Humus Soil	Between 7 and 20

By the table, black cotton soil (BCS) is classified into bad soil. And upper red silt (URC) is classified into normal soil.

・Rock Test

Rock test was carried out for next 3 samples.

Table 6.5.29 Compression strength

BH No.	Rock	Facies	Compression strength (MPa)
NBH4	Basalt	Highly weathered gravelly core	7
NBH7	Basalt	Fresh columnar core	25
NBH12	Basalt	Decomposed core	12

This result shows change of strength on the process of rock weathering. Generally, rock type is classified from A class to D class corresponding to degree of weathering. It is as follows.

Table 6.5.30 Rock Grade

Rock Grade	A	B	C	D
Compression Strength (MPa)	120 over	25 ~ 120	18.5 under	8 under

By this classification, sample of NBH4 is classified into D class. Sample of NBH7 is classified into B class. And sample of NBH12 is classified into C class. But N values of these rocks show more than 50. So these rocks are no problem as bearing layers.

11) **The point of Black Cotton Soil for Execution**

The characteristic of black cotton soil has very high expansiveness compared with normal fine materials. The expansiveness or swell is caused by change of natural moisture content during repeat of rainy season and dry season in a year. In the rainy season,. Swell happens a companied with increase of water content in soil. On the other hand, shrinkage happens a companied with decrease of water content in the dry season. Deformation of ground surface is caused by this repetition. To compare the quantity of water content in soil for rainy season and dry season, it is necessary to get same sample coming from same geological and geomorphological condition site furthermore getting in same depth. So based on the same condition, the comparison of natural moisture content was carried out between samples getting at November, 2003 (dry season) and at September , 2010 (rainy season). The result is as follows.

Table 6.5.31 Rainy Season (September, 2010), Black Cotton Soil

Location	BH No.	Depth (m)	Natural Moisture Content (%)
Plateau	NBH1	2.0 ~ 2.5	41.5
Plateau	NBH2	2.0 ~ 2.5	38.0

Table 6.5.32 Dry Season (November, 2003), Black Cotton Soil

Location	BH No.	Depth (m)	Natural Moisture Content (%)
Plateau	BH10	2.0 ~ 3.0	31.0

By the result, moisture content in the rainy season increases about 9 ~ 10 % compared with the dry season. The relation between change of moisture content and the result of shrinkage test is shown in Table 2.2.2.15. In the table, linear shrinkage value is converted from volume change in shrinkage test into linear change. By the result, when moisture content increases 10 %, linear shrinkage also increases between 2 % and 6 %.(average value 3.6 %). In opposite sense, when moisture content decreases 10 %, linear shrinkage decrease in same ratio to square of side 1 m. Generally, influence of change of moisture content reaches only few meters from the ground surface except cold district. The repetition of swell caused deformation of ground surface. To resolve this problem, black cotton soil should be replaced with low expansive soil or required soil improvement with mixing lime. Furthermore, slope drainage on the road is needed for protect permeation of water to the shoulder of road and the filling slope.

Table 6.5.33 Relation between Natural Moisture Content and Linear Shrinkage

No.	Sta. (Km)	Depth(m)	Soil Type	NMC(%)	SL(%)	R	NMC		NMC+10%			NMC+20%			NMC+30%		
							C(%)	Ls(%)	C(%)	Ls(%)	Rise(%)	C(%)	Ls(%)	Rise(%)	C(%)	Ls(%)	Rise(%)
NTP2	4+000	0.6-2.4	Black Cotton	38.0	11.2	2.1	56.3	14.0	77.3	18.0	4.0	98.3	21.0	7.0	119.3	23.0	9.0
NBH1	5+060	2.0-2.5	Black Cotton	41.5	3.2	2.1	80.7	18.0	101.9	21.0	3.0	123.0	23.0	5.0	144.0	26.0	8.0
NTP7	13+500	0.7-1.4	Upper Brown clay	38.0	8.1	2.3	68.8	16.0	91.8	20.0	4.0	114.8	22.0	6.0	137.8	25.0	9.0
NBH2	14+560	2.0-2.5	Black Cotton	40.0	2.8	2.2	81.8	18.0	103.8	22.0	4.0	125.8	24.0	6.0	147.8	26.0	8.0
NBH3	20+080	2.0-2.5	Black Cotton	38.0	1.9	2.2	61.8	15.0	101.4	21.0	6.0	123.4	23.0	8.0	145.4	26.0	11.0
		3.0-3.5	Black Cotton	45.0	4.4	2.1	85.3	19.0	106.3	22.0	3.0	127.3	24.0	5.0	148.3	26.0	7.0
NBH4	22+040	2.0-2.5	Black Cotton	37.8	3.8	2.1	71.4	17.0	92.4	20.0	3.0	113.4	22.0	5.0	134.4	25.0	8.0
		2.5-3.0	Black Cotton	34.7	7.3	2.1	57.5	14.0	78.5	18.0	4.0	99.5	21.0	7.0	120.5	23.0	9.0
NTP13	23+000	0.5-3.0	Black Cotton	33.0	5.7	2.3	62.8	15.0	85.8	19.0	4.0	108.8	22.0	7.0	131.8	25.0	10.0
NTP15	26+320	0.7-3.0	Black Cotton	53.0	9.2	2.1	92.0	20.0	113.0	22.0	2.0	134.0	25.0	5.0	155.0	27.0	7.0
NBH6	26+500	2.5-3.0	Black Cotton	40.1	6.2	2.0	67.8	16.0	87.8	19.0	3.0	107.8	22.0	6.0	127.8	24.0	8.0
NTP19	32+000	0.0-2.5	Upper Red Clay	35.0	15.1	1.9	37.8	10.0	56.8	14.0	4.0	75.8	17.0	7.0	94.8	20.0	10.0
NTP25	42+500	0.7-3.0	Upper Red Clay	31.0	16.8	1.9	27.0	8.0	46.0	12.0	4.0	65.0	15.0	7.0	84.0	19.0	11.0
NBH10	44+060	2.0-2.4	Upper Red Clay	35.3	15.1	1.9	37.4	10.0	57.4	14.0	4.0	76.4	17.0	7.0	95.4	20.0	10.0
NBH11	47+420	2.5-3.0	Black Cotton	42.3	6.8	2.1	74.6	17.0	95.6	20.0	3.0	116.6	23.0	6.0	137.6	25.0	8.0
NBH12	48+900	2.0-2.5	Black Cotton	43.1	7.8	2.0	70.6	16.0	90.6	20.0	4.0	110.6	23.0	7.0	130.6	25.0	9.0
NBH13	49+200	2.0-2.5	Black Cotton	30.5	10.7	2.0	39.6	10.0	59.6	14.0	4.0	79.6	18.0	8.0	99.6	21.0	11.0
NTP30	49+500	0.0-2.4	Upper Brown clay	36.0	14.1	1.9	41.6	11.0	60.6	15.0	4.0	79.6	18.0	7.0	98.6	21.0	10.0
NBH13-2	50+200	2.0-2.5	Upper Red Clay	21.3	2.5	2.1	41.6	11.0	60.6	15.0	4.0	79.6	18.0	7.0	98.6	21.0	10.0
NTP31	50+500	0.0-2.7	Black Cotton	46.0	12.5	2.1	30.4	16.0	91.4	20.0	4.0	112.4	22.0	6.0	133.4	25.0	9.0
NTP35	56+500	0.8-2.3	Upper Red Clay	41.0	14.4	2.0	53.2	13.0	73.2	17.0	4.0	93.2	20.0	7.0	113.2	22.0	9.0
NTP40	63+000	0.0-2.6	Upper Red Clay	43.0	18.3	1.9	46.9	12.0	65.9	16.0	4.0	84.9	19.0	7.0	103.9	21.0	9.0

12) Material Survey

Material survey is divided into quarry for concrete aggregate and borrow pit for filling material. These existing sites and candidate sites are shown in Table 6.5.34 and Table 6.5.35. New quarry and borrow pit were selected among accessible undeveloped site by car except cultivated land and grazing land. Almost hills and slopes are utilized as settlement and cultivated land along the route. So that reason, the candidate sites are very limited.

Table 6.5.34 List of Quarry Site between Dejen and Debre Markos

Site No.	Location	Offset from A-3 trunk Road	Coordinate	Rock Type	Length (m)	Width (m)	Height (m)	Volume m3 (approximate)	Type of work on site
Q-1	Between Ambesh R. and Yeda R. (Crusher plant of ERA)	0.2Km to the South	0369476E 1136555N	Black, fine and jointed hard basalt	200	200	15	600,000	Sampling of rock (pending)
Q-2	Between Chemoga R. and Ambesh R.	3.5Km to the North	0368376E 1141783N	Weathered basalt with red soil	400	100	-	-	Not good (cancelled)
Q-3	Between Chemoga R. and Ambesh R.	4.0Km to the South	0364818E 1133488N	Black, fine and jointed hard basalt	300	300	20	1,800,000	Boring (10m) pending
AD-2-1	Between Bogena R. and Abeya R. (Old Quarry)	0.7Km to the South	0387855E 1130293N	Black, very hard massive basalt	200	200	20	800,000	Sampling of rock
AD-3	Between Aba Adem R. and Taba R.	1.0Km to the South	0392975E 1129553N	Weathered basalt with red soil	100	100	10	100,000	Not good (cancelled)
AD-4-1	Between Bechet R. and Asametech R. (North of Yetnora village)	3.5Km to the North	0407230E 1134558N	Weathered basalt with red soil	300	300	20	1,800,000	Not bad (pending)
AD-4-2	Ditto	3.0Km to the North	ditto	Black fine and jointed hard basalt	200	200	20	800,000	Boring (10m)
Q-4	Located beside Link Road 23	4.0Km to the North	0404942E 1135268N	Gray black porous Basalt	400	400	10	1,600,000	Boring (10m)
Q-5	South of Dejen Town (ERA's Quarry)	1.0Km from center of Dejen town	0407675E 1122318N	Black fine and jointed hard basalt	400	100	20	800,000	Sampling of Rock

Table 6.5.35 List of Borrow Pit Site between Dejen and Debre Markos

Site No.	Location	Offset from A-3 trunk Road	Coordinate	Rock Type	Length (m)	Width (m)	Height (m)	Volume in m3 (approximate)	Type of work on site
B-1	**Between Ambesh R. and Yeda R. (below Q-1)**	**0.0Km beside A-3**	**0369683E 1136453N**	**Red soil with gravel**	**200**	**300**	**30**	**1,800,000**	**Test Pit (H=5m) PENDING**
AD-5	**Between Ambesh R. and Yeda R. (Borrow pit of ERA)**	**0.4Km to the west**	**0369336E 1135665N**	**Red soil with gravel and highly weathered Basalt**	**300**	**100**	**20**	**600,000**	**Sampling of Soil at 2 sites PENDING**
B-2	**Between Getla R. and Bogena R. (West of Lumame town)**	**0.0Km beside A-3**	**0377378E 1131683N**	**Red soil with gravel and highly weathered Basalt**	**200**	**200**	**20**	**800,000**	**Sampling of Soil at 4 sites**
AD-1	**Between Bogena R. and Abeya R. (East of Lumame)**	**0.5Km to Old A-3**	**0385950E 1132292N**	**Red Soil with rgavel**	**200**	**100**	**20**	**400,000**	**Test Pit (H=5m)**
AD-2-2	**Between Bogena R. and Abeya R.**	**0.0Km Beside A-3**	**0387538E 1131597N**	**Red soil with gravel**	**200**	**100**	**30**	**600,000**	**Test Pit (H=3m)**
AD-6	**Noth of Yetmen Village**	**18.0Km to the north**	**0408162E 1148817N**	**Highly weatheaed Basalt with clay**	**200**	**200**	**20**	**800,000**	**Sampling of Soil**

・Result of Laboratory Test for Concrete Aggregate

The test result is shown in Table 6.5.36. The materials for test are gotten in operating or temporary quarry except Q4 site. Q4 site is wasteland outcropping basalt. On the site Q4 and AD4-2, borings were carried out to get samples of basalt. The content of laboratory test is as follows.

Density and Absorption Test (AASHTO T-85)

Los Angeles Abration Test (AASHTO T-96)

Crushing Strength Test (BS812)

Soundness Test (AASHTO T-104)

Table 6.5.36 Result of Laboratory Test for Quarry Material

Sr No	Location (Km)	Site№	type of Sample	Geological Formation	Density and Absorption (AASHTO T-85)				Los Angeles Abration (ASHTO T-96)		Crushing Strength (BS 812 : 1990)	Soundness (Na2SO4) (ASHTO T-104)
					Density (Dry)	Density (SSD)	Apparent Density	Absorption (%)	Grading Class	LAA %	ACV %	Soundness Loss %
1	South of Dejen1.4km	Q5	Block Core	Jointed Basalt	2.892	2.936	3.026	1.5	B	14	11	0.5
2	6+780, Rt. 4.4km	Q4	Block Core	Jointed Fresh Basalt	2.741	2.819	2.973	2.8	B	14	13	0.5
3	9+000, Rt. 2.3Km	AD4-2	Block Core	Slightly Weathered Basalt	2.922	2.966	3.057	1.5	B	12	11	1.1
4	24.6Km, Lt. 700m	AD2-1	Block Core	Porous Basalt Forming Cliff	2.834	2.882	2.976	1.7	B	15	15	0.7
5	6.78Km, Rt. 18km	AD6	Block Core	Yellowish Gray Meta-Basalt	2.889	2.938	3.040	1.7	B	12	11	0.7

- Density and Absorption Test

Generally density of concrete aggregate is between 2.55 and 2.7 and absorption of it is between 0.5 % and 3.5 %. By the test result, the density is between 2.741 and 2.992 and absorption is between 1.5 % and 2.8 %. So this basalt is no problem as concrete aggregate.

- Los Angeles Abration Test

This test is utilized for check of stability as aggregate for pavement. By the Japanese Industrial Standard (JIS), limit of abration for pavement is 35 %. By the test result, the abration is between 12 % and 15 %. This basalt is no problem as concrete aggregate.

- Crushing Strength Test

This test is carried out to check the strength of aggregate. By the Japanese Industrial Standard (JIS), crushing value should be under 30 % for fine aggregate. By the test result, crushing value is between 11 % and 10 %. So this basalt is no problem as concrete aggregate.

- Soundness Test

This test is carried out to check the durability for weathering. By the specification of concrete based on the Japan Road Association, the loss of mass should be under 10 % for fine aggregate and under 12 % for coarse aggregate. By the test result, the loss of mass is between 0.5 % and 1.1 %. So this basalt is no problem as concrete aggregate.

・Result of Laboratory test for Filling Material

Filling materials are gotten on hills and hill slopes without land use. These materials contain upper red soil (URC) and highly weathered decomposed basalt (DBa). The laboratory tests were carried out for specific gravity, moisture content, Atterberg limit, CBR test and permeability test. The test result is shown inTable 6.5.37, and Table 6.5.38. Furthermore CBR test was carried out for lime mixing black cotton soil to check the change of strength. The test result of CBR is shown in

Table 6.5.39.

Table 6.5.37 Result of Laboratory Test for Borrow Pit Material（1）

Sr. No	Site №	Location (km)	Geological Formattion	Depth (m)	% pass (mm) 2.000	0.425	0.075	LL %	PL %	PI %	Soil Classification (AASHTO)	Particl Size: Sand% (2.0-0.06 mm)	Silt% (0.06-0.02 mm)	Clay% (<0.002 mm)	OMC %	MDD T-180 g/cm³	3 - Point CBR %: 10 blows Density g/cm3	CBR	Swell %	30 blows Density g/cm3	CBR	Swell %	65 blows Density g/cm3	CBR	Swell %	Specific Gravity	LS %
7	AD2-2	25.46, Rt.	Reddish brown clayey silt	0.0 - 3.0m	97	96	95	74	41	33	A-7-5 (20)	4.17	61.07	31.76	35.0	1.525	1.211	1	6.76	1.347	3	5.44	1.431	4	3.61	2.833	19
5	AD1	28.00, Lt. 700m	Reddish brown sand, clayey silt	0.0 - 3.0m	100	99	98	68	39	29	A-7-5 (20)	12.19	62.39	25.42	25.0	1.468	1.230	2	4.64	1.434	6	4.20	1.517	7	3.30	2.824	18
6					100	99	98	66	37	29	A-7-5 (20)	11.02	63.22	25.76	29.0	1.548	1.257	2	5.60	1.432	6	4.11	1.503	7	2.90	2.758	18
1	B2	40.60,Rt.	Yellowish brown silty gravel	S1	30	20	15	61	37	24	A-2-7 (0)	15.97	11.04	2.60	10.8	2.050	1.861	35	0.33	1.987	78	0.21	2.063	89	0.17	2.823	16
2			Yellowish,grayish sandy, clayey silt	S2	100	100	95	80	48	32	A-7-5 (20)	7.70	62.33	29.81	28.0	1.350	1.120	2	10.29	1.271	2	10.29	1.334	2	10.29	2.739	19
3			Grayish brown silty gravel	S3	36	22	16	54	36	18	A-2-7 (0)	21.87	12.84	1.43	15.5	1.970	1.808	36	0.58	1.916	51	0.42	2.003	85	0.10	2.869	14
4			Brown gravelly silt	S4	86	79	73	75	47	28	A-7-5 (19)	17.00	54.35	14.63	28.5	1.430	1.208	2	10.29	1.347	2	10.29	1.391	2	10.29	2.852	20
8	AD6	6.78Km, Rt. 18km	Yellowish, grayish brown silty gravel	S1	30	19	14	55	38	17	A-2-7 (0)	17.31	10.95	1.93	15.3	1.980	1.747	17	0.80	1.957	62	0.38	1.969	106	0.35	2.799	13
9		Blend of 40% AD6 with 60% AD1			47	40	38	64	37	27	A-7-5 (5)	11.54	26.41	8.99	22.0	1.770	1.491	3	2.57	1.677	10	2.53	1.805	15	1.92	2.799	18
10		Blend of 60%AD6 with 40%AD1			68	64	62	62	36	26	A-7-5 (15)	12.00	40.03	16.18	20.0	1.972	1.608	7	1.34	1.779	21	0.85	1.832	23	0.81	2.864	18

LL=Liquid Limit、PL＝Plastic Limit、PI＝Plastic Index、OMC＝Optimum Moisture Coutent、MDD＝Maximum Dry Density、LS=Linear Shrinkage Limit

Table 6.5.38 Result of Laboratory Test for Borrow Pit Material (2)

Sr. No	Site №	Location (km)	Geological Formattion	Depth (m)	% pass (mm) 2.000	% pass (mm) 0.425	% pass (mm) 0.075	LL %	PL %	PI %	Soil Classification (AASHTO)	Particl Size Sand% (2.0-0.06 mm)	Particl Size Silt% (0.06-0.02 mm)	Particl Size Clay% (<0.002 mm)	OMC %	MDD T-180 g/cm^3	3 - Point CBR % 10 blows Density g/cm3	10 blows CBR	10 blows Swell %	30 blows Density g/cm3	30 blows CBR	30 blows Swell %	65 blows Density g/cm3	65 blows CBR	65 blows Swell %	Specific Gravity	LS %
1	AD7	9.00, Rt. 2.5km	Reddish brown clayey silt	0 - 1m (S1)	100	100	98	63	35	28	A-7-5 (19)				26.0	1.400	1.202	1	2.43	1.343	9	2.30	1.434	15	1.97	2.687	18
2				1 - 2m (S2)	100	99	98	70	34	36	A-7-5 (20)	11.94	50.32	37.74	30.5	1.500	1.280	4	2.47	1.410	10	2.30	1.494	19	0.94	2.709	20
3				2 - 3m (S3)	99	97	96	69	35	34	A-7-5 (20)	-	-	-	29.0	1.458	1.260	2	5.14	1.357	4	4.52	1.428	6	2.98	2.725	20
4			Brown sandy, silt clay	0 - 2m (S1)	100	99	97	70	34	36	A-7-5 (20)	-	-	-	26.5	1.525	1.218	1	7.10	1.392	3	7.04	1.482	4	4.45	2.786	20
5				2 - 3m (S2)	70	65	63	67	37	30	A-7-5 (16)	-	-	-	25.5	1.653	1.385	3	2.66	1.601	9	2.35	1.654	11	2.12	2.786	19
6				3 - 4m (S3)	100	99	96	72	35	37	A-7-5 (20)	11.01	46.90	42.09	29.5	1.480	1.238	3	7.86	1.393	4	6.28	1.468	4	4.04	2.941	19
7			Reddish brown sandy clayey silt,	0 - 1m (S1)	96	95	93	62	33	29	A-7-5 (20)	9.50	64.65	25.86	30.0	1.520	1.254	3	3.20	1.399	9	2.66	1.530	11	2.02	2.732	18
8				1 - 2m (S2)	71	67	65	67	42	25	A-7-5 (15)	-	-	-	32.0	1.519	1.390	8	1.71	1.465	12	1.28	1.507	13	1.11	2.865	18
9				2 - 3m (S3)	80	75	72	66	37	29	A-7-5 (19)	-	-	-	27.5	1.549	1.349	7	3.48	1.456	10	2.93	1.514	10	2.38	2.890	18
10	AD8	11.36, Lt. 370m	Grayey silty gravel	S1	40	34	32	60	38	22	A-2-7 (2)	9.08	28.86	2.38	20.2	1.640	1.446	4	6.02	1.551	4	5.49	1.667	5	3.77	2.900	16
11	AD9	11.36, Lt. 570m	Yellowish brown silty gravel	S1	58	35	30	66	47	19	A-2-7 (1)	29.45	25.96	2.60	19.3	1.780	1.359	10	1.02	1.499	39	0.98	1.595	55	0.94	2.793	11
12	AD10	1.68, Lt. 800m	Reddish, Yellowish brown sandy silt	S1	97	95	93	70	35	35	A-7-5 (20)	-	-	-	27.0	1.542	1.266	2	7.51	1.439	4	6.50	1.553	4	3.42	2.741	20
13				S2	100	96	88	70	40	30	A-7-5 (20)	15.28	49.47	25.88	27.5	1.601	1.294	3	2.44	1.496	5	4.97	1.563	6	5.96	2.915	18

LL=Liquid Limit、PL＝Plastic Limit、PI＝Plastic Index、OMC＝Optimum Moisture Coutent、MDD＝Maximum Dry Density、LS=Linear Shrinkage Limit

Table 6.5.39 Resut of CBR test for Mixed Lime Sample

Sr. No	Site点№	Geological Formation	Lime (%)	Atterberg Limit Test						3 - Point CBR % Mixed Lime Sample											
				Before CBR			After CBR			OMC %	MDD T-180 g/cm³	10 blows			30 blows			65 blows			
				LL %	PL %	PI	LL %	PL %	PI			Density g/cm3	CBR	Swell %	Density g/cm3	CBR	Swell %	Density g/cm3	CBR	Swell %
1	NTP 2 (ETP1)	Darkgray silty clay	2%	65	46	19	79	51	28	25.0	1.505	1.248	2	0.12	1.260	4	0.18	1.308	9	0.39
2			4%	52	42	10	65	48	17	25.0	1.501	1.396	2	0.27	1.392	14	0.13	1.415	11	0.25
3			6%	56	42	14	64	50	14	24.0	1.490	1.513	3	0.72	1.473	17	0.21	1.495	17	0.12
4	NTP 13 (ETP2)	Darkgray silty clay	2%	71	46	25	67	47	20	18.0	1.562	1.254	4	1.08	1.564	6	0.98	1.636	11	0.94
5			4%	53	42	11	59	47	12	23.0	1.560	1.327	6	0.12	1.454	12	0.25	1.554	19	0.13
6			6%	51	44	7	51	46	5	23.0	1.540	1.304	11	0.20	1.432	20	0.21	1.509	50	0.15
7	NTP30 (ETP3)	Darkgray silty clay with red silt band	2%	68	45	23	71	47	24	30.0	1.448	1.206	3	0.23	1.346	6	0.21	1.435	7	0.15
8			4%	54	41	13	57	46	11	33.0	1.395	1.195	7	0.21	1.329	16	0.18	1.401	31	0.13
9			6%	50	46	4	53	46	7	32.0	1.369	1.177	13	0.32	1.330	42	0.12	1.404	64	0.11

OMC＝Optimum Moisture Content、MDD＝Maximum Dry Density

- Filling Material

At the alluvial plain in Abeya River and Yeda River, enbankment with about 3m height is planed.. It is desirable that the material has enough strength, low compressibility and suitable natural moisture content. Furthermore trafficability is also important for earth work. Silty gravel in B2 site and sandy, silty red soil in AD1 and AD7 are suitable for filling material. Also gravelly soil in AD6 is suitable but the site is very far being 18 km from national road A3. Gravelly soil in AD9 is also good material but amount of reserves is very few. Upper red soil in AD7 has enough quantity and strength. So it is available for filling material.

- Replacement Material

Along the route, black cotton soil is extensively distributed on the lowland and the plateau. As previously stated, black cotton soil has high expansiveness and low strength. So upper part of black cotton soil should be replaced with good soil. For replacement material, the property is provided by Ethiopian Field Survey Manual (ERA, 2002). as follow:

CBR = over 5

By the test result, the materials of B2 (S3), AD6 and AD9 are silty gravels with CBR values over 5, and upper red silts in AD1, AD7 and AD10 show CBR value more than 5.

- Result of CBR Test for Mixed Sample with Lime

Special CBR test was carried out for black cotton soils of ETP1 (Dejen on plateau), ETP2 (Abeya River) and ETP3 (Yeda River). These black cotton soils were mixed with lime at the rate of 2 %, 4 % and 6 %. By the test result, mixed samples at the rate of 4 % and 6 % changed their properties remarkably. The plasticity index shows under 20 and CBR value shows more than 5, and furthermore expansiveness declined notably. But it seems that use of this material causes big increase of construction cost.

- Result of Permeability Test

The permeability test results of AD1,AD6,AD7,AD9, and AD10 are shown in Table 2.2.2.21. More detailed investigation will be conducted in Detailed Design Stage.

Table 6.5.40　Result of Permeability Test

Sr.№	TP №	Sample №	Depth（m）	Dry Density（kg/m^3）	Coefficient of Permeability K（cm/sec）	Formation
1	AD7(TP1)	S-1	0.00-1.00	1375	2.50×10^{-5}	Reddish brown clayey silt
2	AD7(TP1)	S-2	1.00-2.00	1380	2.53×10^{-5}	Reddish brown clayey silt
3	AD7(TP1)	S-3	2.00-3.00	1364	2.47×10^{-5}	Reddish brown clayey silt
4	AD7(TP2)	S-1	0.00-2.00	1368	2.49×10^{-5}	Reddish brown clayey silt
5	AD7(TP2)	S-2	2.00-3.00	1362	2.46×10^{-5}	Reddish brown clayey silt
6	AD7(TP2)	S-3	3.00-4.00	1392	2.50×10^{-5}	Reddish brown clayey silt
7	AD7(TP3)	S-1	0.00-1.00	1360	2.46×10^{-5}	Reddish brown clayey silt
8	AD7(TP3)	S-2	1.00-2.00	1380	2.23×10^{-5}	Reddish brown clayey silt
9	AD7(TP3)	S-3	2.00-3.00	1390	2.44×10^{-5}	Reddish brown clayey silt
10	AD9	S-2	-	1498	1.05×10^{-5}	Yellowish gray silty gravel
11	AD10	S-1	-	1370	2.49×10^{-5}	Reddish brown clayey silt
12	AD10	S-2	-	1395	2.48×10^{-5}	Reddish brown clayey silt
13	AD1	-	-	1370	2.49×10^{-5}	Reddish brown clayey silt
14	AD1+AD6	MixedSample	(40%+60%)	1834	4.69×10^{-5}	Reddish brown silty gravel
15	AD1+AD6	MixedSample	(60%+40%)	1794	4.19×10^{-6}	Reddish brown clayey silt with gravel