SITE INVESTIGATION ON BAZO RIVER FOR BRIDGE CONSTRUCTION AT GARDA-MARTA AND MALE WOREDAS' ETHIOPIA

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ABSTRACT

Site investigation for different Infrastructures plays a vital role for examining the suitability of the site for different proposed construction projects. Since, it is the surveys for different factors which can be positive and/or negative influence on required activities during design and construction stages. In addition to this, site investigation is needed in order to have long life, economical and functional of different structures [5], [8].

Bridge is civil engineering structure, which has different function for given community as per social, economic, and political aspects. It is commonly built over a river, a dry valley or any depressed part of land to provide a link between the two opposite sides. Thus, before construction of such projects their site investigation is quit important.

Bazo River is found in between two (Garda-Marta and Male) Woredas in Gamo zone, Ethiopia. This river has high discharge capacity of $409.7\text{m}^3/\text{s}$ at dry season and $854.2\text{m}^3/\text{s}$ wet season. But it was stayed without any function for the community just starting from peoples settled in the area. Hence, this research was directed to assess the site for bridge and diversion work.

The main objective of this research study was Site Investigation on Bazo River for Bridge construction at Garda-Marta and Male Woredas, Ethiopia. Therefore, the study covers the feasibility of the site for bridge construction, hydrological data collection; and geotechnical investigation and analysis on subsoil materials [2], [7]. In addition to bridge foundation soil investigation, road subgrade soil investigation was also conducted to have soil class and load bearing behavior for future pavement design.

Keywords: Site investigation, hydrological data, geotechnical investigation, Subgrade, bridge foundation.

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1. INTRODUCTION

In the civil engineering the main issue is planning, investigation, designing and construction of various structures to improve the life of society. Site investigation before construction of different projects is quit important to have confident judgments during different construction phases, safe structure and good function [7], [13].

The rivers are managed well and can meet the interest of human beings like for irrigation, water supply etc. On the other hand, they might bring a numerous negative impact on socio economic life like flooding, lack of accessibility between countries, societies if it is not managed well [5].

Bazo River is found between Garda-Marta Woreda; Gamo Zone and Male Woreda; South Omo zones; Ethiopia. At which People living in two zones are near to each another and similar living style but they have difficulties to reach for their day to day activities. Thus, there is no communication of side to side communities, especially at rainy seasons. Therefore, this research was needed to study on site investigation on Bazo River for Bridge between Garda-Marta and Male Woredas, Ethiopia. Hence, the study covers the feasibility of the site, hydrological data collection and analysis and geotechnical investigation on subsoil materials; which is to provide possible condition to cross the river for stated communities as much as possible.

2. STATEMENT OF THE PROBLEM

As described in introduction, peoples living near Bazo River have common culture, economic sources like farm land around the river, market and religion institutions. But they have no chance to share such important social, political, economical and cultural habits to each other. This was their long period questions particularly, Male and Garda-Marta Woredas. Otherwise they are forced to go very long distance, which is more than 20 to 30km. Thus; these two communities are not share schools, health centers, market, religion institutions and other related socio-economic aspects. Hence, the lack of communication between these two communities (Male Woreda and Marta Woreda) is considered as bottleneck for their every day to day activity.

In addition to this, there is loss of animals, women's, children's and old ages as per community. All the above problems are because of deep, wide and full flow of river throughout the year; and inaccessible for the community.

3. OBJECTIVES OF THE STUDY

General objective is Site Investigation on Bazo River for Bridge and Diversion Head Work construction at Garda-Marta and Male Woredas, Ethiopia

3.1. Specific Objectives

- To study the project area and to select suitable bridge site in order to create communication between two communities
- To investigate for hydrological date of the catchment for bridge design and construction

- To investigate river embankment for Geotechnical parameters and to classify the soil according to AASHTO soil classification system for bridge design and construction

4. MATERIALS AND RESEARCH METHODOLOGY

4.1. Site Condition Survey

For most bridge investigations access and environmental constraints have major influences on planning, designing, construction stages and cost of the given project. It is therefore required for a site condition survey to be conducted as the first stage of any investigation.[5]

Site condition survey was considered to be the main activity for getting site information. It is required in this research to collect hydrological data, to select sample soil test pit areas, to categorize the topography and weather conditions of the study area. Site condition survey is helpful to have confidence to judge on findings for the problem. Site conditions and observed problems of the research area are presented in section 5.

4.2. Hydrological Data

Hydrological survey is necessary to identify the types of data that will be required for the engineering analysis. A well planned hydrological data collection program leads to an orderly and effective analysis and design that is commensurate with, project scope, project cost, and the complexity of site hydraulics. In addition, data collection for a specific project must be tailored to site conditions, social, economic and environmental requirements, and unique project requirements. For this research, hydrological survey was conducted and prepared under the direction of the Ethiopian Roads Authority (ERA) to establish basic design techniques for economical design of surface drainage structures like bridges. [5], [7]

4.3. Geotechnical Investigation

Geotechnical investigations are the main part of construction, which are needed to characterize the soil and soil material for different engineering projects. It was involved with the exploration of subsurface conditions and retrieval of test data for generating geotechnical parameters and geotechnical profiles. [12]

For this research, geotechnical investigation is required to have soils behavior in Bazo River embankment, which is suitable or not for bridge construction. To do so, four test pits were selected at proposed bridge site to investigate soil for bridge foundation and road subgrade. Hence soil samples were collected at 0.6m for road subgrade characterization and 3m, 4.5m and 6m depth variation for bridge foundation characterization.

This research work began by conducting laboratory experiments on four soil samples collected to find out their various geotechnical properties for road subgrade and bridge foundation characterization. For these purpose, summer of geotechnical investigations conducted were presented in table 1 below.

Table 1 Summary of Tests Conducted, Standards, And Their Significance

S.No	Tests conducted	Test method/standard	Pits investigated	Remark
1	In-situ moisture content (w)	AASHTO T 265 or ASTM D 2216	For 4 pits	For bridge foundation and road subgrade
2	Liquid limit(LL)	AASHTO T89 / ASTM D 4318	For 4 pits	For both bridge foundation and road subgrade
3	Plastic Limit (PL)	AASHTO T90/ ASTM D 4318	For 4 pits	
4	Sieve analysis	AASHTO T 88 / ASTM D 422	For 4 pits	
5	Moisture- Density Relations of Soils	AASHTO T180-97 / ASTM D2937	For 4 pits	
6	Shear strength test	ASTM D3080 Direct shear test	For cohesion less soil pits	For bridge foundation only
		ASTM D2166 Unconfined Compressive Strength of Cohesive Soil	For cohesive soil pits	
7	CBR and swell at OMC and MDD	AASHTO T-193 and T-180	For 4 pits	For road subgrade only (taken at 60cm depth)

The soils under investigation were classified according to AASHTO M-145 by using grain size analyzed and Atterberg's limit test performed. This classification system was used to group and indicate the behavior of soil materials that can be used for foundation material bridge and road subgrade [1], [3], [4].

5. RESULTS AND DISCUSSION

5.1. Feasibility Study and Site Selection

As per methods used, the proposed bridge and bridge site was selected at narrow river channel, good embankment, straight river approach. As well the site was at accessible location for both Male and Marta Woreda communities. These all requirements were needed to have functional for the community, strong and durable structurally, least cost economically. Having these points under consideration, the bridge site which is feasible was shown in figure below.

Figure 1 Specific site of Bazo river site **Figure 2** Bridge site from Google earth

Table 2 Global coordinate location of test pits

Pits	Longitude/Northing	Longitude/Easting	Elevation a.m.s.l(m)	Topography/Terrain of the area
Pit 1 at Marta side, U/S	5°53'06"	37°00'24"	826.00	Plain (0-10%)
Pit 2 at Marta side, D/S	5°53'05"	37°00'23"	825.84	
Pit 3 at Male side, U/S	5°53'07"	37°00'21"	826.51	
Pit 4 at Marta side, D/S	5°53'04"	37°00'22"	826.42	

As per table 2 above, the research area is totally wide plain topography covered by cultivated land for different agricultural products. Coordinate points are taken (as shown in figure3) from just the embankment of river to have characterize soil nature for bridge.

5.3. Land use Land Cover of the Catchment

The land use land coverage condition of catchment was almost cultivated land and used for settlement of people at mountains area and most likely shrub land at middle part around bridge site. The exposures of catchment area for rainfall due few of Natural forest coverage currently result high erosion of area and high flood condition which also results on some portion of area of catchment land sliding. On other hand above 43% of catchment is covered by the agricultural or crop land. The river banks currently change its natural morphologic condition slightly due to exposure of river back for erosion found in river bank simply rolling to river by river bank erosion and resulting transportation of massive sediment transport along river.

Figure 3 Land use land cover map of Bazo River catchment

5.4. Hydrological Analysis

The proposed bridge site has not gauged stream flow data, but the design of bride needs a long period of stream flow data. Though, long record length (1980-2008), is effectively used in the transfer of the long period flow condition from gauged station to the proposed bridge site (Bazo River site) using relation analysis. This requires the similarity of watershed characteristics between the gauged and ungagged sites and the ratio of basin area should be within 0.5 to 1.5 as [13]. The quality of data should be tested for some errors before transferring. Outlier test is commonly used for checking observation errors significantly from

the bulk of the data may be due to errors in data collection, recording, or due to natural causes. For this particular study, Grubbs T-test was used to identify outlying observations.

The Grubbs T test statistic (T) is calculated as;
$$T = \frac{x - \bar{X}}{s}$$

Where: X - is observed mean monthly flow, $\bar{X}$ - is the mean of observed mean monthly flow, and S is the standard deviation of observed mean monthly flow during 1980-2008 for the test. According to this test, nine outliers were observed and filled by using annual average method.

Then the drainage area of bridge site and the gauge site were computed by GIS and the spatial data like Digital elevation model DEM were obtained from <http://www.usgs.gov/EE>. As this the area of Bazo is 2169km² whereas at Woito is 4522km². This is important aspect in the design of drainages structure particularly bridge. It is possible to calculate peak discharge for this site condition by using drainage area ratio method as [13], [16]

$$Q_{\text{ungauged}} = Q_{\text{gauged}} * \left(\frac{A_{\text{ungauged}}}{A_{\text{gauged}}} \right)^x$$

Where Q is discharge, A is area at gauged site and project site and x is slop exponent.

Figure 4 The location of the study area data transfer from gauged point

Figure 5 Daily maximum and average monthly flow over 28 year (extended)

As per figure 6; from the 28 years data of flow in the Woito River the project site peak discharge computed for Bazo River area and computed 310.81 m³/s in July and 409.7 m³/s in November. Hence, the peak discharge 409.71m³/s will be used for design purpose which is termed as design discharge (Qd).

5.5. Geotechnical Investigation

A detailed and accurate knowledge of geology and geotechnical is an essential part of construction and hazard analysis in a civil engineering structure. The geology of an area dictates the location and nature of civil engineering structures such as dam, bridge, building and tunnels. However, for any civil engineering project, detail geological investigations play an important role for the safety and economic feasibility of the project. Because, most of civil engineering structures fail before design period of time due to geological effects. Hence the geological factors should be studied before designing the structures. These geological factors determine the alignment and stability of roads and bridges by the effects of topography, lithology (rock & soil types), Geological character, Weathering rate and Ground water condition are the most important factors [6], [12], [11].

Geotechnical investigation was conducted for two purposes. First one was soil investigation for bridge foundation whereas second part was investigation for road subgrade characterization [8], [9]. The geotechnical investigation is conducted of soil samples were taken at 3m to 6m from both sides of the bridge.

Figure 6 Direct shear test of soils at male side pit 3 at 4.5m depth

Figure 7 describes about direct shear test for soils for Male side pit 3 at 45m depth to determine shear strength parameters; angle of friction (ϕ) and cohesion (C). This figure is used as sample to present how the test was conducted on soil samples taken from different depth for given four pits. Shear strength parameters for specified pit 3 at 4.5m were determined from Applied stress vs shear stress at failure; which 21° and 11.19 kN/m^2 angle of friction and cohesion respectively.

Figure 7 Unconfined shear strength chart for Marta side; pit 2 at 6m depth

Figure 7 presents, unconfined shear strength test to determine undrained shear strength of soils from unconfined shear value of soils. Again it is needed as sample for this test on male side pit 2 at 6m depth. From this chart unconfined shear value (q_u) was read from chart as 173.1kPa to calculate soil undrained shear strength (C_u) of 86.50kPa for pit 2 at 6m depth of Marta side. By similar manner as shown in figure 6 and 7, different geotechnical investigations at different depth were conducted and collected to summary in table 3 below.

Table 3 Summary of Geotechnical investigation test results for bridge

Side	pit s	Depth(m)	Sieve analysis			Atterberg limit test		AASHTO Soil class		Compaction		Soil Shear test		
			%ge of pass by 2.0m m	%ge of pass by 0.425 mm	%ge of pass by 0.075 mm	LL %	PI %	Soil Cla ss	Descript ion	OMC %	MD D (g/c m3	Φ (de g)	C(kN/ m2)	Cu(kN/ m2)
Mar ta	1	3	99.3 3	98.61	93.05	37.6	12. 71	A-6	Silty soil	21.77	1.52	24.7	18.86	-
		4.5	89.2 5	88.4	82.76	30.9 5	10. 06	A-6	Silty soil	24.15	1.5	22.82	20.25	-
		6	97.1 3	89.62	69.2	39.8 8	9.7 4	A- 7-5	Clay soil	23.14	1.5	-	-	96.87
	2	3	99.3 3	98.61	93.05	35.6	10. 71	A-6	Silty soil	19.44	1.55	26.3	18.86	-
		4.5	93.5 2	90.13	86.02	34.1 1	12. 86	A- 7-5	Clay soil	23.53	1.44	-	-	92.9952
		6	98.9	96.8	92.89	69	28. 3	A- 7-5	Clay soil	30.03	1.34	-	-	86.54
Mal e	3	3	97.1 3	89.62	69.2	41.1 3	14. 34	A- 7-5	Clay soil	25.14	1.38	-	-	89.12
		4.5	61.9 1	56.93	38.64	38.6	11. 4	A-6	Silty soil	27.12	1.47	21	11.19	-
		6	67.1 7	61.77	41.92	33.8 8	11. 87	A-6	Silty soil	17.43	1.59	22.79	12.14	-
	4	3	92.2 7	85.14	65.74	40.0 7	14. 62	A- 7-6	Clay soil	26.93	1.36	-	-	87.83
		4.5	90.4 3	83.43	64.43	42.0 3	12. 05	A- 7-5	Clay soil	22.47	1.43	-	-	92.35
		6	83.2 9	76.78	57.37	33.7 5	10. 12	A-6	Silty soil	24.94	1.5	20.32	19.07	-

As per geotechnical investigation for bridge foundation; soils at both sides are fine grained. Thus at Garda-Marta side soil is silt (A-6) up to 4.5m depth and at 6m depth it is silt (A-6) soil whereas at Male side soil is clay (A-7-5) at 3m and silt at 4.5m depth and silt (A-6) at last 6m depth[1], [15].

Soils at Garda-Marta side is clay (A-7-5) with undrained shear strength of 96.87kn/m2 and 86.54kN/m2 at 6m for pit 1 and 2 respectively whereas soil at Male side is silt (A-6) with direct shear strength of angle of friction 20.32 to 22.79 and cohesion 19.07 to 12.14kN/m2 at 6m depth for pit 3 and 4 respectively; which clay soil properties [3], [14].

Table 3 is the summary of geotechnical investigation for bridge foundation for geotechnical design. Especially shear strength parameters at different depth of investigation are quit important to define bridge footing and abutment for loads from superimposed and supper structure.

Table 4 Geotechnical investigation for road subgrade soil classification

Pits	Side	Depth(m)	Sieve analysis% ge of pass			Moisture content w%	Atterbeg's Limit			Soil classification AASHTO M145
			2mm	0.425mm	0.075mm		LL %	PL %	PI %	
1	Marta	0.6	95.24	83.4	62.89	23.18	42.71	31.63	11.08	A-7-5 Clay Soil
2		0.6	85.5	68.19	51.96	35.23	49.87	36.66	13.21	A-7-5 clay soil
3	Male	0.6	92.33	74.01	54.1	43.58	46.16	33.31	12.85	A-7-5 Clay Soil
4		0.6	95.14	86.28	71.96	42.99	45.77	26.57	19.2	A-7-5 clay soil

From table 4 above, as per investigation of soils for road subgrade in both sides is fine grained A-7-5 soil classification. It has PI of 11.08 to 19.20%. These results present road subgrade soil is fair to poor subgrade rate as per AASHTO M145. For road subgrade strength; compaction for optimum moisture content (OMC %) and maximum dry density (MDD g/cm³), CBR and swell were conducted as shown figure 9 below.

As per geotechnical investigation for road subgrade; Soil at both Marta and male sides are clay; *A-7-5 with different level of bearing (CBR values)* as per AASHTO. Subgrade soil is also categorized as subgrade class S₃ (pit 3 and 4 those have CBR value ranged in 5 to 8%) and S₄ (pit 1 and 2 those have CBR value ranged in 9 to 14%) [5], [10].

Figure 8 Geotechnical investigation on subgrade soil strength

No allowance for CBRs below 3% has been made because, from both a technical and economic perspective, it would normally be inappropriate to lay a pavement on soils of such poor bearing capacity. For such materials, special treatment is required [5]. Thus, the use of Class S₂ (those have CBR value ranged in 1 to 3%) soils as direct support for the pavement should be avoided as much as possible. Wherever practicable, such relatively poor soils should be excavated and replaced, or covered with an improved subgrade.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

Finally, site investigation for bridge construction cross Bazo River has different findings which is to linking the communities' overall activity. So that, having the investigation findings, the following conclusions can be drawn:

- From site investigation and repeated evaluation of the research area by different engineering experts, relatively good site which is feasible for bridge construction was

selected as shown in figure 3. And the hydrological results shows that the research site peak discharge is 310.81 m³/s in July and 409.7 m³/s in November. Hence, the peak discharge 409.71m³/s will be used as design discharge (Qd).

- Soils found at Bazo river embankments is layered with clay and silt soils in different depths. These were revealed that soil at Marta side is silt up to 4.5m and clay at 6m whereas at Male side is clay at top and silt at bottom depth as table3 by AASHTO M145 classification system. Therefore, it was concluded as soils at research site are dominated by fine grained soil class.
- For road subgrade soil investigation, compaction test result shows that Plastic index ranges 11.08% to 19.20%, optimum moisture content (OMC %) ranges from 16.52% to 22.89% whereas maximum dry density (MDD g/cc) ranges from 1.496 to 1.71 g/cc, CBR ranges from 5.69% to 20.54% with percentage of swelling 1.07% to 3.13%. for road subgrade soils.
- For bridge construction soil investigation, Soils at Marta is clay (A-7-5) with undrained shear strength of 96.87kN/m² and 86.54kN/m² at 6m for pit 1 and 2 respectively whereas soil at male side is silt (A-6) with direct shear strength of angle of friction 20.32 to 22.79 and cohesion 12.14kN/m² to 19.07 kN/m² at 6m depth for pit 3 and 4 respectively.

6.2. Recommendations

As findings described in trying to conduct this research has revealed areas where further efforts may be proved in the future during construction phase. Following are some of the points recommended which are related to the study:

- This research was conducted without deep investigation lower than 6m; hence it may need to explore foundation soil and soil material for further finding by different soil investigation machines. And also the soil at river embankment is usually saturated so that it is recommended to investigate soils under saturated conditions. Since, soil characteristics may vary with different conditions, like moisture.
- It is recommended to carry out similar site exploration for different infrastructures' for future developments on such unaccessed areas to have possible solution of communities.

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