THE UNITED REPUBLIC OF TANZANIA

THE SELANDER BRIDGE EXPANSION PROJECT

ENGINEERING REPORT

JUNE 1980

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

It is with great pleasure that I present this report entitled the Engineering Report for the Selander Bridge Expansion Project to the Government of the United Republic of Tanzania.

This report embodies the result of a detailed design survey which was carried out (in Dar es Salaam, Tanzania) from June 1st to June 12th, 1980 by the Japanese survey team commissioned by the Japan International Cooperation Agency following the request of the Government of the United Republic of Tanzania.

The survey team, headed by Dr. Nobuyuki Narita, had a series of close discussions with the officials concerned of the Government of the United Republic of Tanzania and conducted a wide scope of field survey and data analyses.

I sincerely hope that this report will be useful as a basic reference for development of the region.

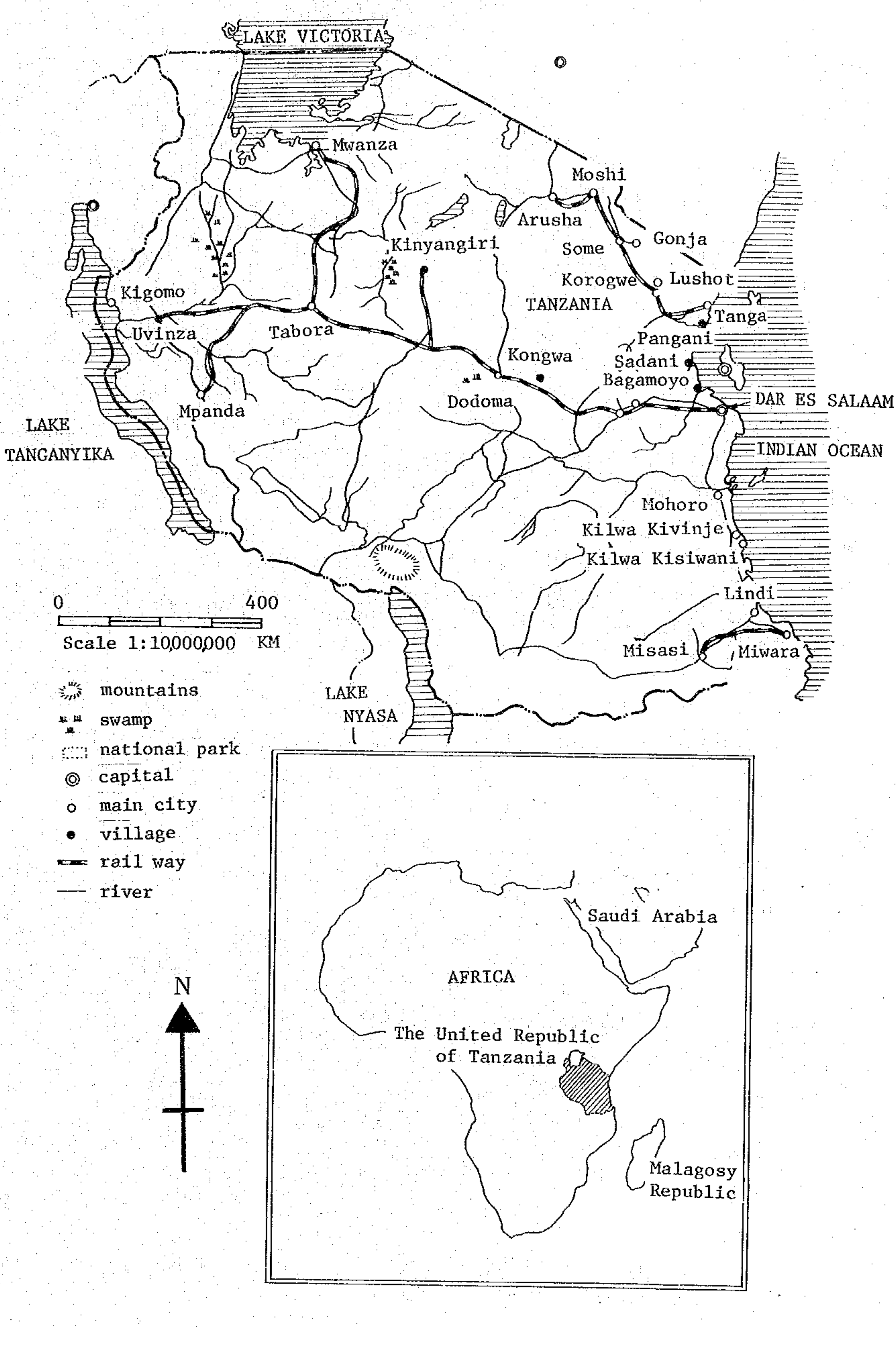
I am particularly pleased to express my appreciation to the officials concerned of the Government of the United Republic of Tanzania for their close cooperation extended to the Japanese team.

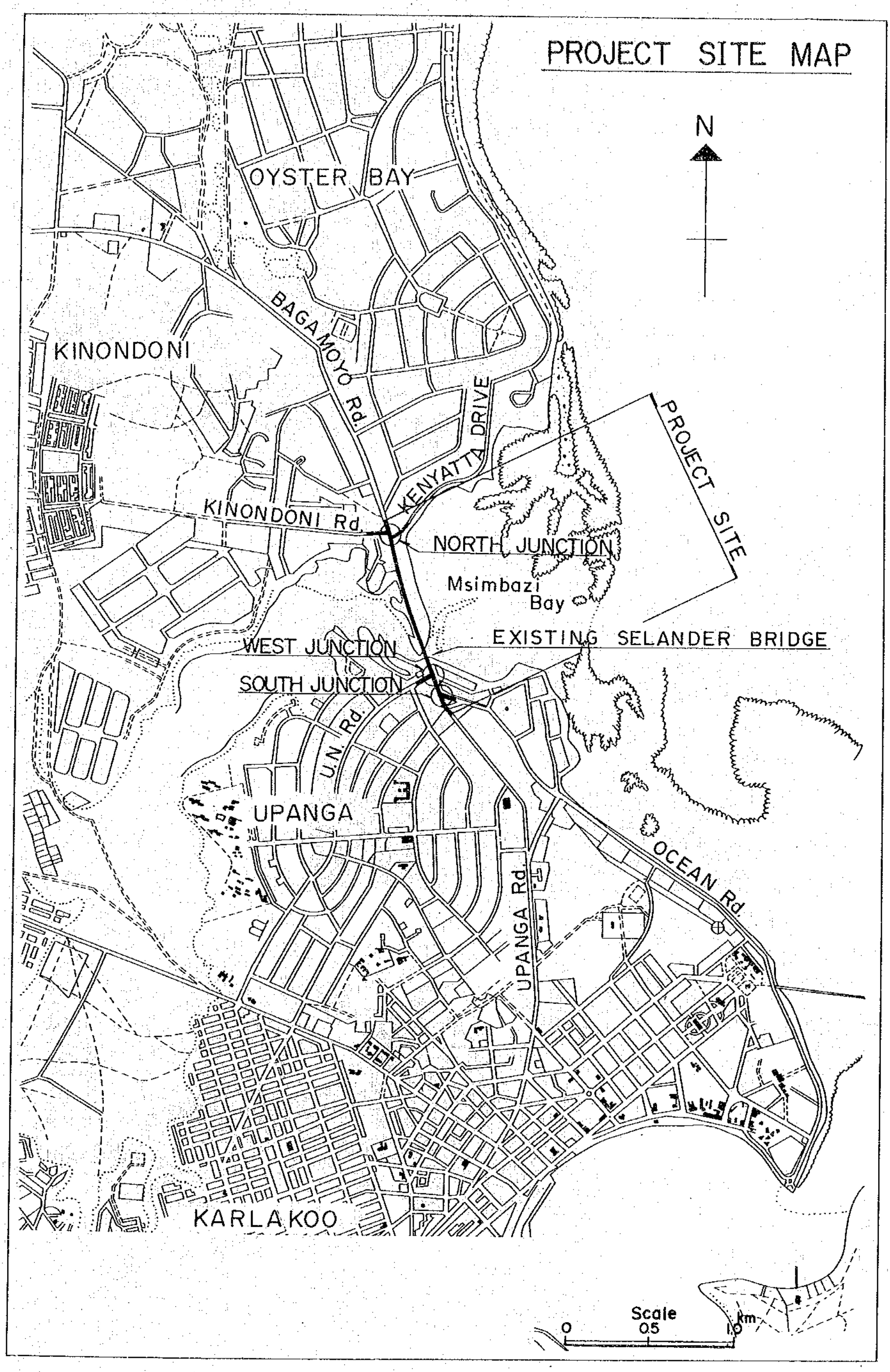
June, 1980

Keisuke Arita

Keisuke Arita
President
Japan International Cooperation Agency

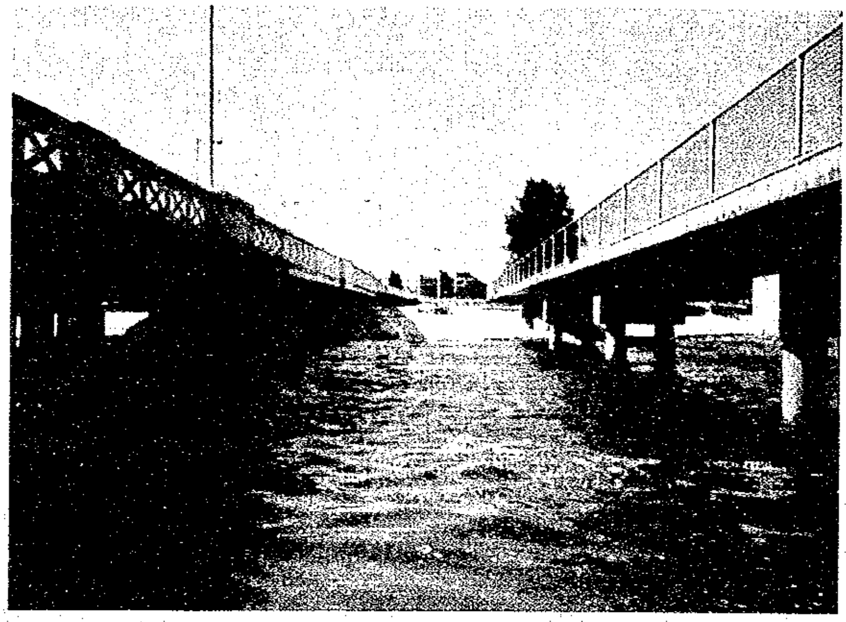
LOCATION MAP





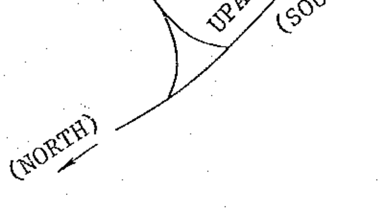
PROJECT SITE MAP
N
OYSTER BAY
KINONDONI
BAGAMOYO Rd.
KENYATTA DRIVE
PROJECT SITE
KINONDONI Rd.
NORTH JUNCTION
Msimbazi
Bay
EXISTING SELANDER BRIDGE
WEST JUNCTION
SOUTH JUNCTION
U.N. Rd.
UPANGA
UPANGA Rd.
OCEAN Rd.
KARLAKOO
Scale
0
0.5
1.0
km

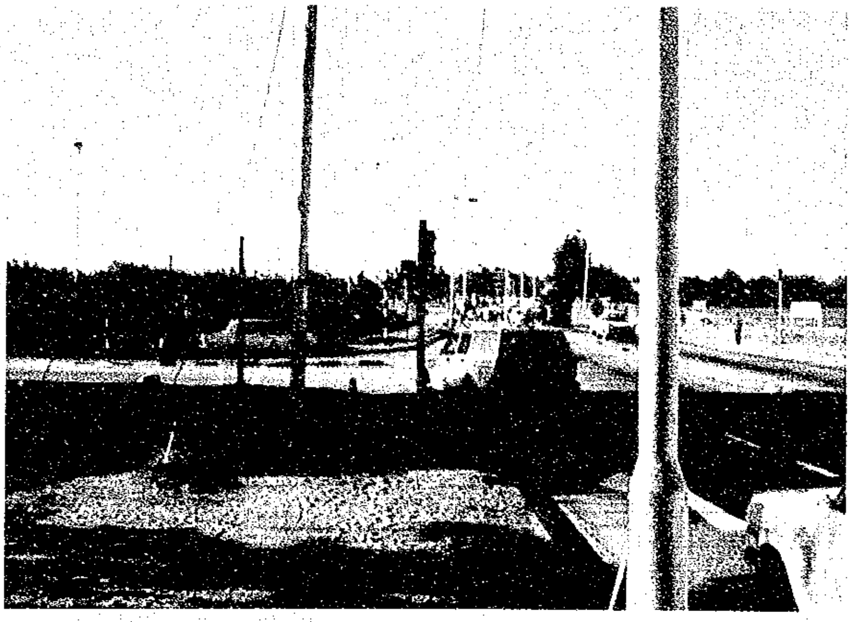
PRESENT CONDITION OF THE PROJECT ROAD (SELANDER BRIDGE AND SOUTH JUNCTION)



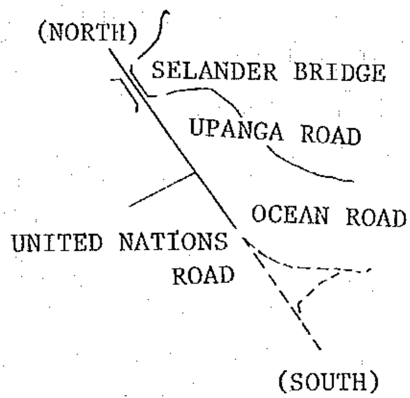
SELANDER BRIDGE (LEFT) AND PEDESTRIANS BRIDGE

SOUTH JUNCTION (1)

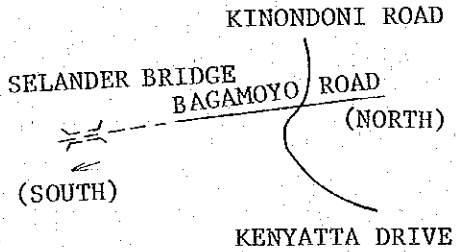


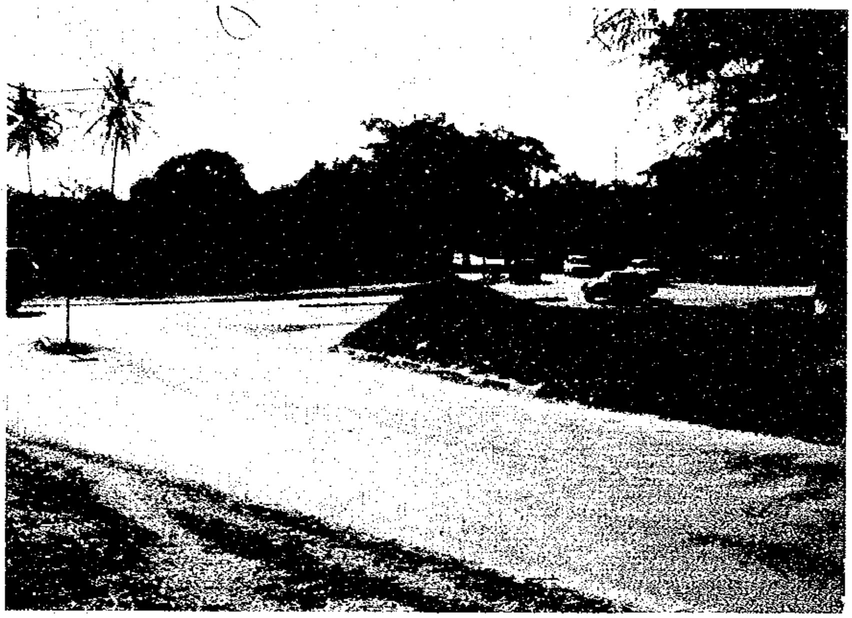


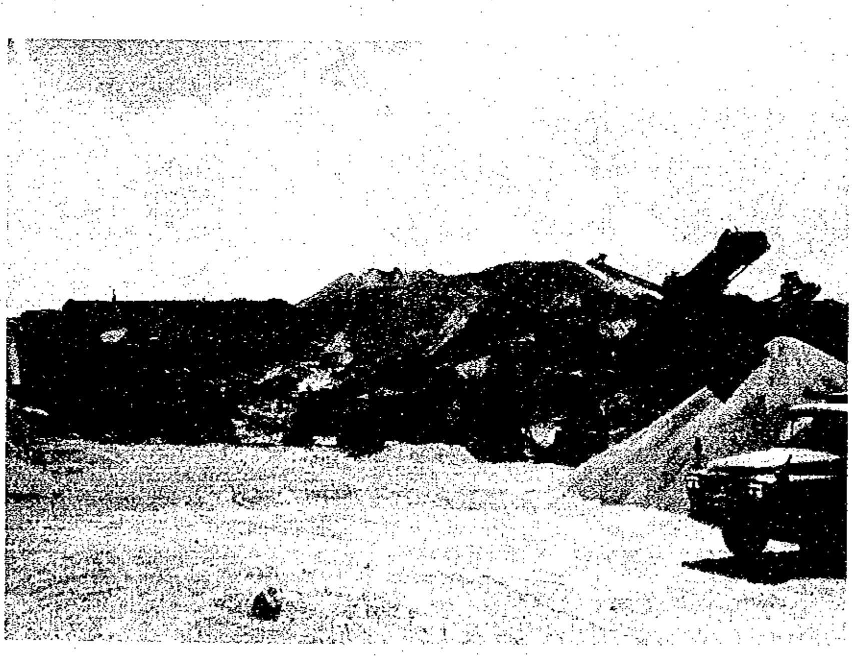
SOUTH JUNCTION (2)



NORTH JUNCTION







KUNDUCHI

CRUSHING PLANTS AT KUNDUCHI

SUMMARY

SUMMARY

(01) This Project envisages to improve a section of very important and the only arterial road which connects the downtown district of Dar es Salaam City, the capital of the United Republic of Tanzania, and the northern residential area. Rush hour traffic in this road section already exceeds the capacity of the road and is causing excessive traffic congestion.

(02) In the future, the ratio of heavy vehicles to all traffic, as well as the volume of traffic as a whole, will inevitably increase in this road section, and the arterial road will no longer be able to perform its functions unless improved accordingly. The objective of this Project is to adequately meet such anticipated future traffic demand by constructing a new bridge in place of the existing Selander Bridge and by improving the approach road sections of about 1.2 kilometers in total length connecting with both ends of the bridge.

(03) As a result of the survey and deliberation with the government conducted by the Preliminary Survey Team dispatched to Tanzania in September 1979 in response to the request of the Tanzanian Government, this Project has been taken up as a project of Japanese grant-aid cooperation. A Basic principle for design was then established as a result of discussions between Tanzanian Authorities concerned and the Basic Design Survey Team, which was sent to Tanzania in December 1979. Detailed design prepared in accordance with the Basic principle has been presented in this Report and outlined hereunder.

Basic Principle for Design

(04) The existing Selander (carriageway) Bridge is to be retained and used as a pedestrian/bicycle bridge in the future, while the existing pedestrian bridge is to be demolished. A new bridge with four drive lanes and a pedestrian/bicycle track is to be constructed on the ocean side of the existing bridge.

(05) The project bridge and road are to be planned to accommodate the predicted future traffic volume in 1990 which is determined as target year of the Project plan. The traffic volume in the year was estimated at 38,700 vehicles per day or 3,000 vehicles per hour at the stage of basic study of the Project. The traffic volume is used as the basis for the planning and design of the Project. As for the rate of right-turn traffic to total traffic at West junction, 30% is to be used.

(06) With the exception of the British Standards applied to the design load of the new bridge, Japanese design standards are to be used for the design of the bridge, the road, and the traffic control facilities.

(07) It was agreed by the Tanzanian Government that, in principle, the government removes all the items which will hinder the execution of this Project work prior to the commencement of the construction work.

An Outline of Design

(08) The new Selandar Bridge is to be constructed on the ocean side of the existing bridge as a reinforced concrete bridge with the length of 75.75 meters. The two carriageways are to be completely separated from each other by a distance of 1.5 meters. Each carriageway is to have two drive lanes, and the ocean side carriageway is to have a 4-meter wide pedestrian/bicycle track. The type of the bridge is determined to be a 5-span continuous hollow-slab bridge, in consideration of not only economic aspect but also construction condition at the site and environmental aspect. The typical cross section of the new bridge is shown in Fig. S-1.

(09) This bridge, which is located in a shore area, will be exposed to the effects of salt. Therefore, bridge accessories are to be of a corrosion resistant material. Bearing shoes and expansion joints are to be of rubber, and hand rails are to be of aluminum.

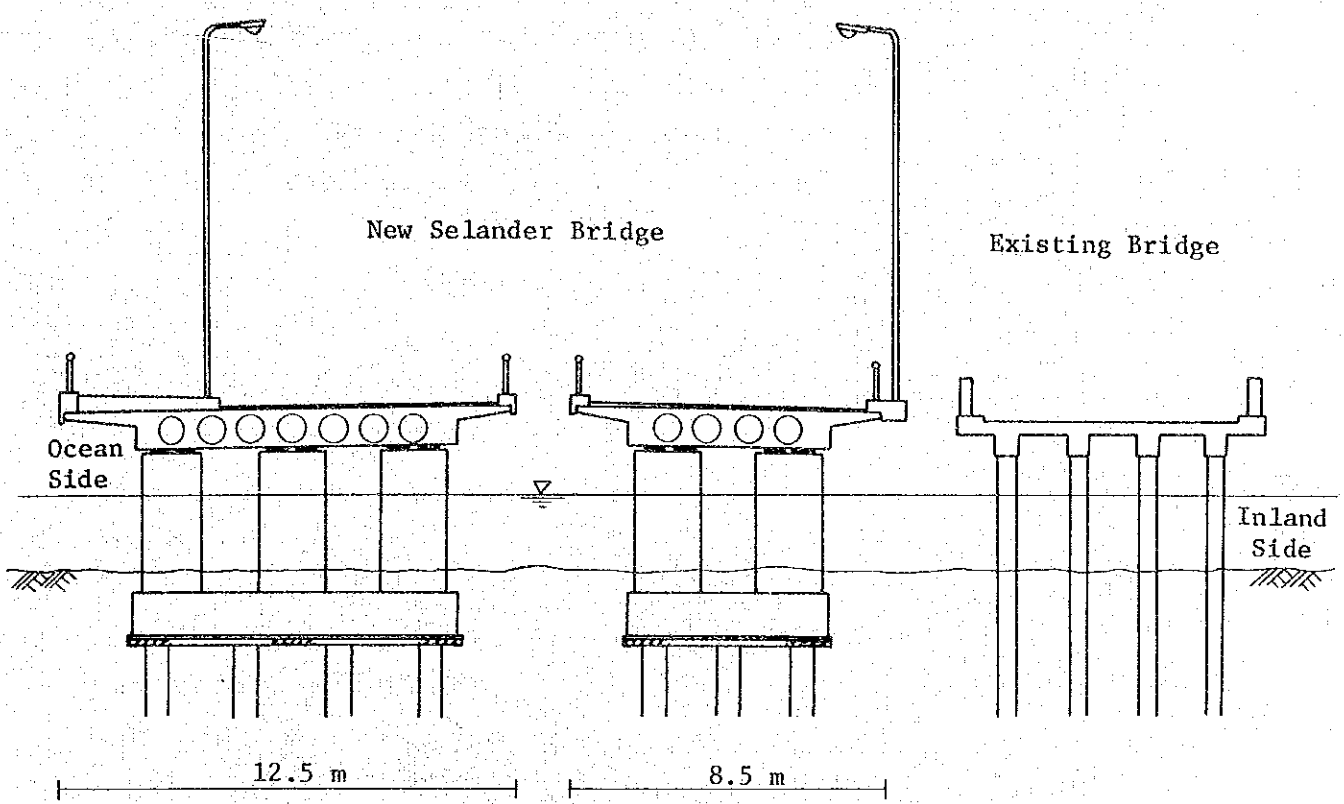


Fig. S-1 Cross Sectional View of Planned and Existing Selander Bridge

(10) The bridge site is covered with a thick and soft layers of deposited sand and silt over a relatively compact layer of coral of a greyish white color, under which lies a very hard white coral layer. The layers with N value of 30 or higher is regarded as acceptable bearing layer for the bridge foundation load. The bearing layer for this bridge declines from south to north and reaches a maximum depth of 30 meters from the ground. Therefore, in consideration of workability, the bridge foundation structure is determined to be of steel pipe piles.

(11) Future traffic volume on this section is estimated at 38,700 vehicles per day in the target year, which classifies it as a Class 1 in Category 4 road by the Japanese Highway Design Standards. In accordance with the Standards the design speed is determined at 60 kilometers per hour in roadways and 40 kilometers per hour in junctions. The typical cross section of the roadway is shown in Fig. S-2.

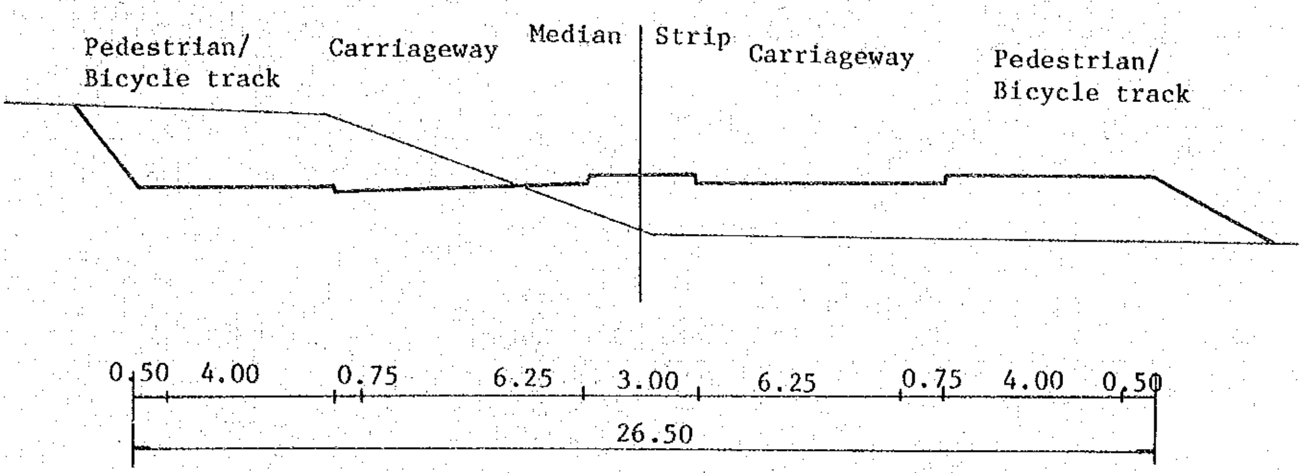


Fig. S-2 Typical Roadway Cross Section (unit:meter)

(12) This Project involves three junctions. In order to expand the traffic capacity at these junctions, they are to be provided with traffic signals and waiting, right-turn, left-turn, and channelization lanes.

(13) The carriageway pavement will be of plant-mixed asphaltic concrete. Design of pavement is as shown in Fig. S-3, which is determined based on the CBR value of the subgrade soil of 12 and on the heavy vehicle traffic volume in the target year of 830 per day in one direction. The bridge surface pavement will be of the same material as that of the surface course of roadway but will be 5 centimeters in thickness. Pedestrian/bicycle track pavement will be composed of 10 centimeters thick crusher-run sprayed with asphalt as dust-proof treatment.

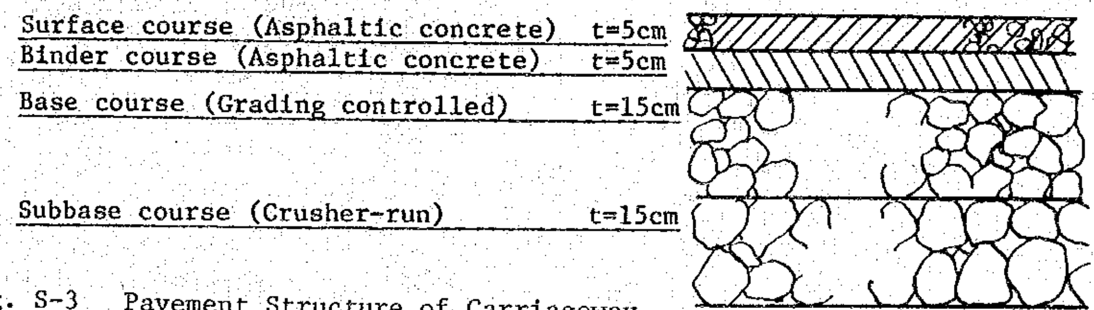


Fig. S-3 Pavement Structure of Carriageway

(14) The entire road sections will be provided with road lighting. Lighting poles will be installed at intervals of approximately 30 meters. In order to facilitate smooth flow of traffic and safety of pedestrians, the roads will also be provided with road signs and road markings.

(15) Construction work of the Project is scheduled to be commenced in September, 1980 and completed in March 1982 with construction period of 18 months. It is considered that the construction work can be continuously proceeded even in rainy season.

(16) In advance of commencement of construction work of the new bridge, the existing pedestrian bridge, which will obstruct the construction of the new bridge, must be demolished and removed. To avoid any construction work in water, river bed area along the new bridge route will be raised to sufficient elevation with soil embankment leaving minimum necessary river width for water pass. For construction of piers, steel sheet piles will be driven surrounding the pier sites before excavation work to prevent water leakage to the pier construction site.

(17) The present traffic through the existing bridge not allowed to be shut down even during construction period, because no suitable detour can be provided economically. Therefore, the construction of the Project work shall be executed stagewise and sectionwise always providing some road width for passage of traffic.

(18) The quantities of the major items of work of this Project are as follows :

Total extension	:	1,177 meters
Bridge length	:	75.75 meters
Cutting	:	3,570 cubic meters
Embankment	:	10,940 cubic meters
Pavement area	:	20,800 square meters

Bus stop	:	One place
Signals	:	30 sets
Lights	:	94 sets

Main Feature of the Project

1. Bridge

Superstructure	:	5-span continuous reinforced concrete hollow-slab
Substructure	:	Multi-concrete wall with steel pipe pile foundation
Length	:	75.75 meters (15.00 meters x 5 spans)
Width	:	Ocean side : 11.50 meters (7.50 meters carriageway + 4-meter pedestrian/bicycle track) Inland side: 7.50 meters
Pavement	:	Asphaltic concrete Carriageway : 5-centimeter thick Pedestrian/bicycle track : 3-centimeter thick
Superelevation	:	2%
Load	:	HA load
Reference load	:	HB load (45 units)
Seismic coefficient	:	0.05

2. Road

Standard	:	Category 4, Class 1 Road
Design speed	:	Roadway : 60 kilometers per hour Junctions : 40 kilometers per hour
Width	:	Median strip : 3.00 meters Carriageway : 3.25 meters x 4 drive lanes Shoulder : 0.75 meters Sidewalk : 4.00 meters

Pavement	:	Design value of CBR : 12 Subbase course : Crusher-run, 15-centimeter thick Base course : Grading controlled, 15-centimeter thick Binder course : Asphaltic concrete, 5-centimeter thick Surface course : Asphaltic concrete, 5-centimeter thick
Superelevation	:	2%
Junctions	:	Signal controlled
Road lights	:	Entire section

CONVERSION FACTORS AND ABBREVIATIONS

1) Length

mm = millimeter

cm = centimeter

km = kilometer

2) Areas

cm^2 = square centimeter

cm^2 = sq.m = square meter

3) Volume

ℓ = 1,000 cm^3 = litre

m^3 = cubic metre

4) Weight

g = gramme

kg = kilogramme

t = 1,000 kg = ton

KN = 0.102 t = kilonewton

5) Time

sec = second

h = hr = hour

6) Money

$ = US dollar

T.Shs = Tanzanian Shilling

$ = 7.9 T.Shs, 1980 price level

7) Electrical Measures

V = Volt

A = Ampere

kV = Kilovolt

W = Watt

8) Other Measures

% = per cent

P.C.U. = passenger car unit

HP = horse-power

°C = degree centigrade

cd = candle power

lx = lux

nt = nit

9) Derived measures are based on the same symbols :

kg/m^3 = kilogramme per cubic meter

m/sec = meter per second

km/hr = kilometer per hour

t/m^2 = ton per square meter

LIST OF SEPARATE VOLUMES

Constructional Program & Method

Drawings

Design Calculation

Quantity Calculation

LIST OF REFERENCES

British Standards 153 1972
British Standards Institution

Specifications for Highway Bridges 1980
Japan Road Association

Design Standards of Expantion Apparatuses for Highway Bridges 1970
Japan Road Association

Design Standards of Bearing Shoes for Highway Bridges 1973
Japan Road Association

Highway Design Standards 1970
Ministry of Construction, Japan

Design Standards of Guardrail Installation 1972
Japan Road Association

Plan and Design for Junction 1980
Traffic Engineers Society

Alignment Design of Highway 1978
Traffic Engineers Society

Design Standards of Drainage for Highway 1973
Japan Road Association

Design Standards of Asphalt Pavement 1979
Japan Road Association

Preliminary Study Report on the Selander Bridge Expansion Project 1979
Japan International Cooperation Agency

Preliminary Design Report on the Selander Bridge Expansion Project 1980
Japan International Cooperation Agency

Traffic Study and Traffic Design Data 1970
COWI Consultant

Japanese Industrial Standards
Japanese Standards Association

Standards of Japanese Electrotechnical Committee
Japanese Electrotechnical Committee

Standards of Japan Electrical Manufacturers Association
Japan Electrical Manufacturers Association

Handbook of Construction Equipments
Japan Construction Mechanization Association

Prices of Construction Materials and Wages May 1980
Construction Prices Investigation Institute

Japan/East Africa Freight Tariff

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C O N T E N T S

CHAPTER I

BASIC CONCEPTS

CHAPTER 1 BASIC CONCEPTS

1.1 Back Ground

This Project is to improve the most congested section of the arterial road connecting the commercial downtown district of Dar es Salaam, the capital of the United Republic of Tanzania, and a housing area, north of the city. The improvement of this road section has been studied since about 1970 and road improvement is viewed as an important national project. Early commencement of the improvement work is much desired.

In response to the request of the Tanzanian Government and in full recognition of its importance, the Government of Japan has decided to offer grant-in-aid and technical assistance on this Project.

A Preliminary Project Study Team was dispatched to Tanzania for 14 days from September 22 to October 5, 1979. This Team (a) explained the Japanese grant-in-aid system to Tanzanian officials, (b) coordinated with relevant Tanzanian Authorities on this Project and established the Project framework, and (c) conducted surveys and collected data necessary for the subsequent design phase.

In order to facilitate the early implementation of this Project, a Basic Design Study Team was sent to Tanzania on December 1, 1979, based on the findings of the Preliminary Study Team. This Team stayed in Tanzania for 21 days until December 21, 1979, collected data needed for basic design study, conducted discussions with relevant Tanzanian officials on the details of the basic policy, and established policy for the subsequent analysis and design work to be done in Japan.

1.2 Design Principles

The basic concept of this Project and the fundamental plan policy, as determined by the Preliminary Study and Basic Design Study Teams, are as follows:

1) This Project is to construct a new bridge in place of the existing Selander Bridge and to improve the road across the bridge extending for about one kilometer between North Junction and South Junction. The existing bridge is to be retained for continuous use by pedestrian and bicycle traffic, and the new bridge is to be built with 4-lane and a pedestrian/bicycle track on the ocean side. The carriageway width is to be 15 meters, same as that of approach roads on both sides, subject to adjustment should it be necessary to secure a sufficient length of right-turn lanes for both Junctions.

2) For design load of the bridge, HA load by the British Standards is to be used and checked by HB load. In consideration of the corrosive environment, the bridge is to be a concrete structure with 15- to 20-meter span. It is believed that the bridge shape (type) should be finally determined after taking into consideration the ease of materials procurement, workability, administration, and maintenance.

3) Future traffic volume per peak hour per direction in 1990 is estimated at 3,000 passenger car equivalents based on the actual traffic counts done by the Preliminary Study Team and the analysis of available data. The rate of right-turn traffic at West Junction is estimated at 30% of all traffic. Traffic is to be controlled at Junctions by signals. Should traffic volume exceed the traffic capacity, a new route will be established rather than expanding the Project road from the 4-lane road to a 6-lane road, and, therefore, no future expansion was considered in the design. Additionally, traffic control facilities such as road lights, road signs, and road markings are to be installed.

4) Japanese standards will be used for the design of this Project, with the exception of certain British Standards. Japanese materials specifications are to be used as the standards of all materials.

5) Public facilities which can hinder the work of this Project are to be reviewed in detail, and the Tanzanian Government is to be requested to relocate them so as not to adversely affect the progress of the work. Actual conditions of their relocation will be discussed in detail in Chapter 2. The full minutes of discussions between the Tanzanian Government and the Preliminary Study Team and Basic Design Study Team, respectively, are presented in ANNEX A-I and A-II.

CHAPTER 2

OBSTRUCTIONS AND GOVERNMENTAL ASSISTANCE

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2.1 Obstructions

Since it is necessary to clearly identify the obstructions which hinder smooth execution of the Project, an additional field investigation was carried out during the period of 22 May to 3 June, 1980. As a result, the following obstructions were identified :

Item No.	Description of Site Obstruction
1.	Fence lying north of Kinondoni Road
2.	Concrete block lying north of United Nations Road
3.	Hedge and fence located at the west of United Nations Road
4.	Handrail located in front of police station
5.	Police box located in front of police station
6.	Hedge and fence located on the ocean side of Ocean Road.
7.	Existing foot bridge running along the existing Selander Bridge
8.	Underground communication cables and accessories buried in the Project area, currently managed by Tanzania Post & Telecommunications Corp. (hereinafter called as "T.P.T.C.")
9.	Underground communication cable and accessories installed under the foot bridge, owned by the Ministry of Foreign Affairs
10.	Water mains and fittings installed under the foot bridge, managed by Water Supply Corp. (hereinafter called as "W.S.C.")
11.	Street lighting facilities standing in the project area excluding the part of Selander Bridge, managed by Tanzania Electric Supply Co., Ltd (hereinafter called as "TANESCO")
12.	11 kV overhead distribution line suspended in and around each junction, being managed by TANESCO

13. Traffic signal facilities located in the Upanga Rd./ United Nations Rd. junction, owned by TANESCO

The location map showing the obstructions mentioned above is attached as Fig. 2-1.

The Tanzanian Government and the Detailed Design Survey Team discussed, taking into consideration the local conditions and the work schedule, about the sharing of the responsibilities with regard to the obstructions clearing works in the meeting of June 6, 1980. The results of the discussions are detailed in Annex A-III "Gist of Discussions on the Detailed Design on the Selander Bridge Expansion Project".

The major works to be done under the responsibility of the Tanzanian Government are as follows:

(a) Shifting of the obstruction No.8 out of the Project area (to be done by T.P.T.C.);

(b) Shifting of the obstruction No.10 from the foot bridge to the existing Selander Bridge (to be done by W.S.C.);

(c) Removal of the obstruction No.11 out of the Project area (to be done by TANESCO); and

(d) Shifting of the obstruction No.12 out of the Project area (to be done by TANESCO).

As mentioned above, these facilities, installations, structures, etc. will become major obstructions against the smooth execution of the Project construction works. Therefore, it will be necessary that the both parties will make utmost efforts in a close cooperation for removing such obstructions for early completion of the Project.

In addition, it is absolutely required that the Tanzanian Government will give administrative supports to this end.

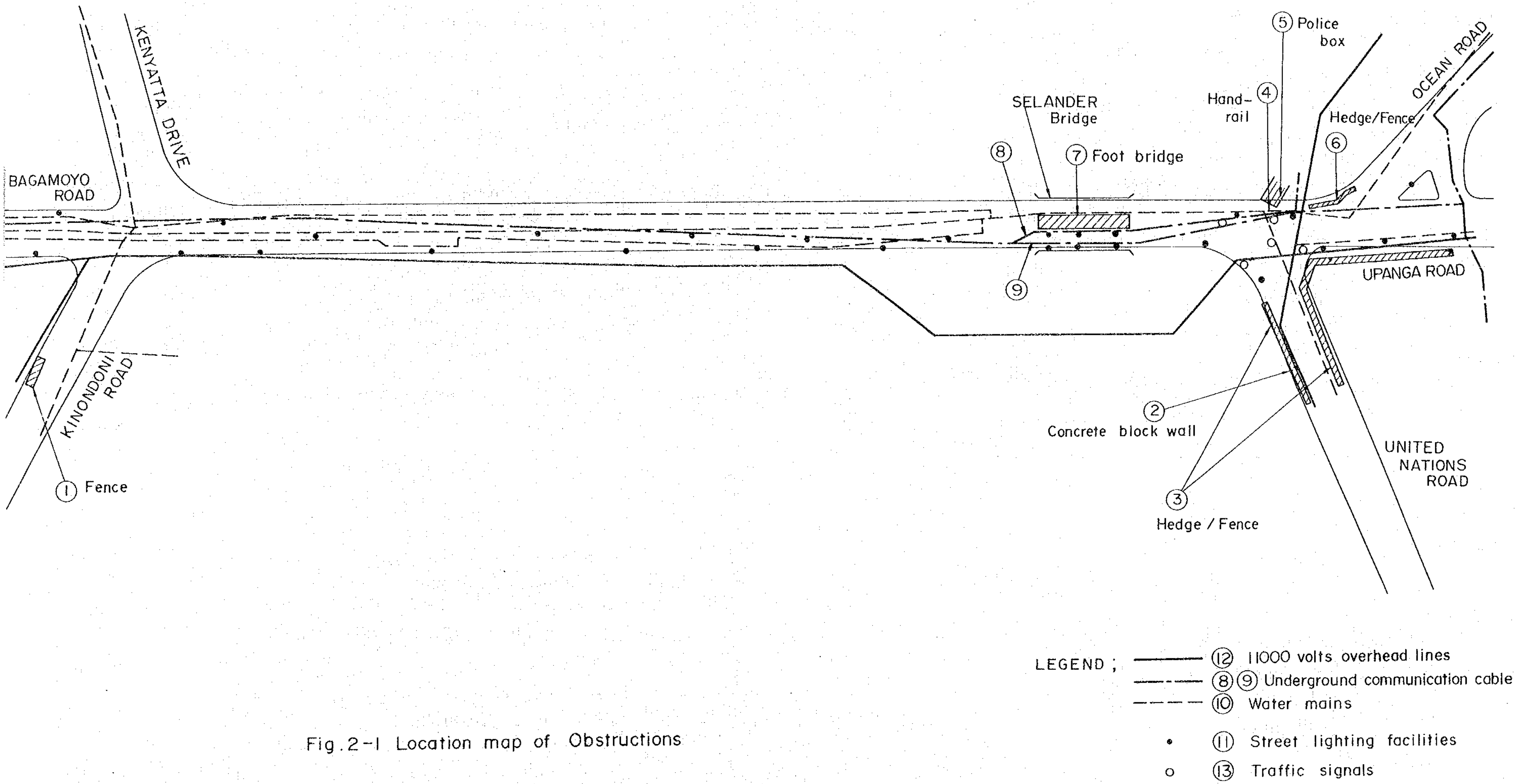


Fig. 2-1 Location map of Obstructions

2.2 Tanzanian Governmental Assistance

In addition to the items in Section 2.1 above, the assistance of the Tanzanian Government is required on the following matters prior to the execution of the works :

1) Material/Equipment Import Tax Exemption

Most of construction materials and equipment needed for the work will have to be imported to Tanzania from abroad. In view of the financial aid to be granted by the Government of Japan, the Tanzanian Government is requested to waive tariff or import taxes and other impositions and to expedite the customs clearance of the necessary materials and equipment to be imported.

2) Temporary Facility Site Aquisition

It is expected that the Tanzanian Government will secure, prior to the work commencement, appropriate land sites for the temporary facilities needed for the work execution to include:

a) Construction materials and equipment yard,
b) Site office and dormitory for the contractor employees,
c) Consultant's office, and
d) Crushing plant and asphalt mixing plant.

3) Local Resources Utilization Permits

Tanzanian Ministry of Works is expected to obtain from the Authorities concerned the necessary mining/quarry rights or permission to allow the collection/production and the transportation of construction materials which are available from local sources, which will include the following :

a) Aggregate produced from Msorwa quarry (130 kilometers to the west of the work site) to be used for surface course and concrete. Aggregate produced from Kunduchi quarry (14 kilometers to the north of the work site) to be used for binder base course, and subbase course.

b) Sand chiefly for use in concrete to be obtained from the Mpiji River basin (some 40 kilometers to the north of the work site).

c) Embankment material (needed only in a limited amount) which is available in the vicinity of the work site to be obtained under the direction of Tanzanian Ministry of Works.

4) Public Facility Use Permission

The Ministry of Works must obtain permission from Authorities concerned for the use of water, electric power, and telephone as needed for the work execution and will install the necessary terminal facilities.

5) Materials Procurement Assistance

The Ministry of Works must help Contractor purchase lumber, gasoline (petrol), kerosene, and other necessary materials in such a manner as to facilitate uninterrupted works progress.

6) Other Arrangements

The Ministry of Works should make the necessary arrangements when, from time to time, discussions and consultation between Contractor and the Ministry and/or other relevant Tanzanian Authorities become necessary on the matters of design, work execution and the test of completed work.

CHAPTER 3

CONSTRUCTION MATERIALS

CHAPTER 3. CONSTRUCTION MATERIALS

3.1 General Use Materials

Construction materials generally used in this Project are identified hereunder, together with their quality standards.

1) Aggregate

Aggregate for pavement or concrete work must be clean, hard, durable, free from long or flaky pieces and from harmful proportions of soil and organic matter, and must mix well with cement without pealing off. The crushed stone produced in the Msorwa area is highly angular, has a sufficient hardness, shows a low abrasion loss rate, and satisfies not only the quality but also quantity requirements of the Project. Aggregate from Kunduchi area is soft and unsuitable for use in surface course or concrete.

The standard grading of aggregate is shown in Table 3-1.

Table 3-1 Standard Grading of Coarse Aggregate (JIS A5005)

Sieve Size (mm) / Classification	Percentage by Weight Passing								
	50	40	30	25	20	15	10	5	2.5
40 ∿ 5	100	95 ∿ 100	–	–	35 ∿ 70	–	10 ∿ 30	0 ∿ 5	–
25 ∿ 5	–	–	100	90 ∿ 100	–	25 ∿ 60	–	0 ∿ 10	0 ∿ 5

2) Sand

Sand needed as fine aggregate for the production of concrete must be clean, hard, durable, and of an appropriate mixture of small and large grains but free from harmful proportions of trash, mud, and organic matter. Sand is available in ample quantities from the roadside shores, but the shore sand, which is of a homogenous grain size and contains salt, will not be used for this project because of the grading and the difficulty of obtaining water needed for pre-washing of the sand for use as concrete material. River sand, which is available from the Mpiji River (about 40 kilometers to the north of Dar es Salaam), will be used.

The standard grading of fine aggregate is shown given in Table 3-2.

Table 3-2 Standard Grading of Fine Aggregate

Sieve Size (mm) / Classification	Percentage by Weight Passing						
	10	5	2.5	1.2	0.6	0.3	0.15
Fine aggregate	100	90 ∿ 100	80 ∿ 100	50 ∿ 90	25 ∿ 60	10 ∿ 30	2 ∿ 10

3) Cement

Cement which is to be used for this construction work will be Portland cement, or, in principle, ordinary Portland cement, which satisfies the Japanese Industrial Standards (JIS) R-5210 or equivalent.

Cement must be stored away from humidity and ventilation at all times, and hardened cement must never be used for the work no matter how low the degree of hardening may be.

Table 3-3 Quality of Portland Cement (JIS R5210)

Item \ Classification		Ordinary Portland Cement
Specific area (cm^2/g)		2900 min.
Setting	Initial setting	After 60 min.
	Final setting	Within 10 hr
Stability		Good
Compressive strength (kg/cm^2)	1 day	-
	3 days	70 min.
	7 days	150 min.
	28 days	300 min.
Hydration heat (cal/g)	7 days	-
	28 days	-
Oxide of magnesium (%)		5.0 max.
Sulphuric anhydride (%)		3.0 max.
Loss on ignition (%)		3.0 max.
Tricalcium silicate (%)		-
Tricalcium aluminate (%)		-

4) Water

Clean water free from harmful oil, acid, alkali, salt, and organic matter must be used. Brine should never be used, particularly for making concrete. Therefore, tap water will be used for this project as a rule.

5) Iron & Steel

Major iron and steel materials to be used in this project are enumerated in Table 3-4, and those with a quality which satisfies the JIS or equivalent must be used. Their transportation and storage must be accomplished with utmost care so as to prevent rusting and other damage.

Table 3-4 Quality of Steel, Iron etc.

Material	JIS NO.	Used for
Steel bars for concrete reinforcement	G3112	Reinforcement structures
Carbon steel tubes for general structure purposes	G3444	Foundation piles
Rolled steel for welded structure	G3101	Temporary bridge, Coffering
Steel sheet piles	A5528	Coffering
Aluminum alloy castings	H5202	Railings
Grey iron castings	G5501	Catch basins

3.2 Bridge Construction Materials

1) Concrete

The concrete used for the floor slab and wheel guards must have a compressive stress of at least 240 kilograms per square centimeter at the age of 28 days. Coarse aggregate with a maximum size of 25 millimeters will be used. The concrete mix is shown in Table 3-5.

Table 3-5 Concrete Mix Proportion for Superstructure (per $1m^3$)

Material	Unit	Proportion
Water	kg	157
Cement	kg	290
Water-cement ratio	%	54.1
Fine aggregate	kg	774
Coarse aggregate	kg	1,140
Admixture	-	used

Substructure concrete must have a compressive stress of at least 210 kilograms per square centimeter at the age of 28 days. Coarse aggregate with maximum size of 40 millimeters will be used.

The concrete mix is shown in Table 3-6.

Table 3-6 Concrete Mix Proportion for Substructure (per 1 m^3)

Material	Unit	Proportion
Water	kg	177
Cement	kg	306
Water-cement ratio	%	58
Fine aggregate	kg	759
Coarse aggregate	kg	1272

2) Expansion Joints

Expansion joints will be of rubber, chiefly of neoprene with a quality which will satisfy the JIS K6301 or equivalent.

3) Bearing

Chloroprene synthetic rubber bearings of a quality equivalent to JIS K6301 will be used.

4) Foundation Piling

Foundation piles are of steel pipes with inner diameter of 600 millimeters and thickness of 9 millimeters which satisfy the requirement of the STK 41 standard of JIS G3444.

5) Backfilling

The limestone to be obtained from Kunduchi will be run through crusher (40 - 0) and used for back-filling (See Table 3092).

3.3 Road Construction Materials

1) Embankment

The results of a soil test indicate that the soil available along the project site belongs to soil classification of SW or SP and is of an adequate quality for use as embankment material. The surface soil (humus) will be removed and the subsoil will be used for embankment. Any embankment material shortage will be supplemented from nearby soil sources.
The standard finish thickness of the each layer of embankment will be 30 centimeters, and the maximum size of the material, 30 centimeters.

For the embankment materials, the standard compaction test used is the method 1.1 under "methods for testing the compaction of soil by tamping" under JIS A-1210 which indicates that the soil should show at least 90% compaction (that is, the rate of dry density after compaction to the maximum dry density, γd max) and soil's contracted water content is within the scope stipulated based on the optimum water content (that is, the scope within which W opt and 90% compaction can be obtained).

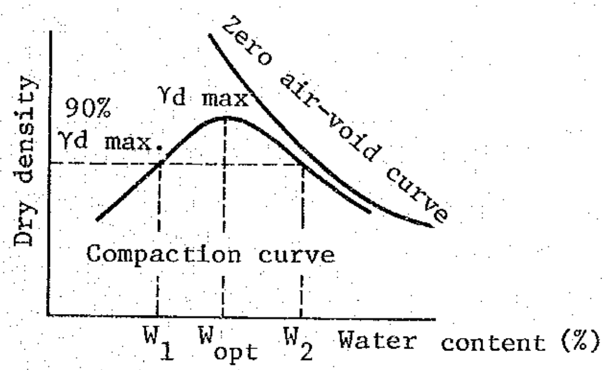


Fig. 3-1 Compaction Curve of Soil

2) Improved Subgrade Material

The strength of subgrade, which directly bears the pavement weight is the base for determining required pavement thickness.

The major function of subgrade is to support traffic load in unity with pavement. In order to achieve this, subgrade must have a sufficient strength and bearing power, show a minimum deformation, and cause a minimum swelling by penetrating water.

Based on a soil investigation findings, a design CBR of about 12% can be expected of the existing road subgrade and therefore, its bearing power will be sufficient in the future. For embankment portions, subgrade material with a CBR of at least 12% will be used.

Based on the soil test findings, it is expected that an adequate quantity of soil will be fully available in the vicinity of the project site. The standard finish thickness of the each layer of subgrade will be about 20 centimeters and the maximum size of the material, 20 centimeters.

Quality standard for subgrade is as follows:

- Design CBR, at least 12%
- Compaction, at least 90% of γd max by JIS A1210
- Contracted water content, about equal to the optimum water content and at least within the level of water content at which γd of 90% can be obtained by the standard tamping test.

3) Concrete Road Structures

In the interest of maximum work speed and minimum inconvenience to the existing traffic during the period of construction, forms (molds) will be brought to the project site for on-site casting of ditches, kerb stones, and other concrete structures for the road which can be field-cast. Tables 3-7 and 3-8 below show the required strength of concrete for these structures and concrete mixes tentatively proposed.

Table 3-7 Requirements of Concrete Structure

Used for	Design Strength (kg/cm^2)	Slump (cm)	Max. Size of Coarse Aggregate (mm)	Remarks
Kerb stone	240 min	8 max.	25	Class A
Concrete cover of side ditch and culvert	210 min	8 max.	25	Class B_1
Culvert	210 min	8 max.	40	Class B_2
Headwall, Foundation of kerb stone	160 min	8 max.	40	Class C
Leveling concrete for substructure	135 min	–	25	Class D

The concrete mix is shown in Table 3-8.

Table 3-8 Concrete Mix Proportion (Per 1 m^3)

Classification	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Water (kg)	Admixture
Class B_1	306	759	1171	177	used
Class B_2	303	694	1267	167	used
Class C	255	720	1272	140	used
Class D	171	812	1382	94	

3.4 Pavement Construction Materials

Materials to be used for pavement work and their quality requirements are as follows:

1) Subbase Course

Crusher-run C-40 will be used. The grading and the quality requirements of crushed stone are as shown below:

Table 3-9 Gradings of Aggregate for Subbase Course

Sieve Size (mm) / Classification	Percentage by Weight Passing				
	50	40	20	5	2.5
C-40	100	95 ∿ 100	50 ∿ 80	15 ∿ 40	5 ∿ 25

Table 3-10 Aggregate Requirements for Subbase Course

Kind of Tests	Requirement	Standard
CBR value	20 % min.	JIS A1211 or equivalent
Plasticity Index of 0.4 mm under size	6 % max.	JIS A1205 or equivalent JIS A1206 or equivalent

2) Base Course (Controlled aggregate grading)

The M-40 classification of controlled aggregate graiding will be used. The grading and the quality standards for controlled grain size M-40 are shown below:

Table 3-11 Gradings of Aggregate for Base Course

Sieve Size (mm) / Classification	Percentage by Weight Passing						
	50	40	20	5	2.5	0.4	0.074
M-40	100	95 ∿ 100	60 ∿ 90	30 ∿ 65	20 ∿ 50	10 ∿ 30	2 ∿ 10

Table 3-12 Aggregate Requirements for Base Course

Kind of Test	Requirement	Standard
CBR value	80% min.	JIS A1211 or equivalent
Plasticity Index of 0.4 mm under size	4 % max.	JIS A1205 or equivalent JIS A1206 or equivalent

3) Binder Course

Coarse grade asphalt concrete (20) will be used. The grading and the quality standards of aggregate are as shown below.

Table 3-13 Gradings of Aggregate for Binder Course

Sieve Size (mm)	Percentage by Weight Passing								
Classification	25	20	13	5	2.5	0.6	0.3	0.15	0.074
20 ∿ 0	100	100 ∿95	90 ∿70	55 ∿35	35 ∿20	23 ∿11	16 ∿5	12 ∿4	7 ∿2

Table 3-14 Marshall Test Requirements for Binder Course

Kind of Tests	Requirement	Remarks
Marshall stability value (kg)	500 min.	
Percentage of void (%)	3 ∿ 7	
Void filled with bitumen (%)	65 ∿ 85	
Compaction time (time)	75	

The following mix is tentatively proposed for the coarse grade asphalt concrete (20):

Table 3-15 Asphalt Mix Proportion for Coarse Grade Asphalt Concrete (20)

Material	Unit	Proportion	Use
Coarse aggregate	m^3	0.496	Crushed stone
Fine aggregate	m^3	0.175	River sand
Filler	t	0.051	
Straight asphalt	t	0.054	Asphalt penetration 60 ∿ 80

4) Surface Course

Drive lanes in embanked sections and bridge lanes will receive a 5-centimeter layer of surface course made of dense grade asphalt concret (13). The standard grade and quality of aggregate for surface course is as follows:

Table 3-16 Gradings of Aggregate for Surface Course

Sieve Size (mm) / Classification	Percentage by Weight Passing							
	20	13	5	2.5	0.6	0.3	0.15	0.074
13 ∿ 0	100	100 ∿ 95	70 ∿ 55	50 ∿ 35	30 ∿ 18	21 ∿ 10	16 ∿ 6	8 ∿ 4

Table 3-17 Marshall Test Requirements for Surface Course

Kind of Tests	Requirement	Remarks
Marshall stability value (kg)	750 min	
Flow value (1/100 cm)	20 ∿ 40	
Percentage of void (%)	3 ∿ 6	
Void filled with bitumen (%)	70 ∿ 85	
Compaction time (time)	75	

The following mix is tentatively proposed for dense grade asphalt concrete (13):

Table 3-18 Asphalt Mix Proportion for Dense Grade Asphalt Concrete (13)

(per 1 ton)

Material	Unit	Proportion	Use
Coarse aggregate	m^3	0.411	Crushed stone
Fine aggregate	m^3	0.255	River sand
Filler	t	0.063	
Straight asphalt	t	0.061	Asphalt penetration 60 ∿ 80

5) Bitumen Materials

Bitumen which shows a penetration of 60 to 80 and which satisfies JIS K2530 will be used for pavement.

Table 3-19 Standard Penetration

Kind of Bitumen	Grades	Temperature	Standards
Straight asphalt	60 ∿ 80	120 ∿ 160°	JIS K2530 or equivalent

6) Aggregate

Aggregate to be used for asphalt pavement must be clean, hard, durable, and free from harmful proportions of long or flaky pieces, clay, and organic or other foreign matters.

Table 3-20 Aggregate Requirements for Surface Course

Use / Kind of Tests	Surface Coarse	Base Course	Remarks
Specific gravity of saturated surface dry aggregate	2.45 min	-	
Absorption (%)	3.0 max.	-	
Abrasion rate (%)	30 max.	50 max.	

7) Filler

Limestone, dust or crushed igneous rock with a moisture content of 1.0% or less and which is free of granules must be used as filler. The filler materials should never be allowed to get wet in storage.

The standard gradings of filler material is as follows:

Table 3-21 Gradings of Filler

Sieve Size (mm) / Classification	Percentage by Weight Passing		
	0.6	0.15	0.074
Filler	100	100 ∿ 90	100 ∿ 70

CHAPTER 4

BRIDGE DESIGN

CHAPTER 4. BRIDGE DESIGN

4.1 Design Plans

It has been planned that the new Selander Bridge will be built adjacent to the existing bridge on its ocean side. Since the topography of the bridge construction site includes a developed sand bank forming a raised ground on the north side, it has been decided that the bridge abutment on the north side will be located about 10 meters ahead of the existing abutment and accordingly, the bridge length will be about 75 meters. The bridge will have completely separate carriageways, one for each direction, with a distance of 1.5 meters between them.
Each carriageway will have two lanes with a width of 6.5 meters. The effective width of the bridge on the inland side is 7.5 meters including the shoulder, while that of the bridge on the ocean side is 11.5 meters with a 4-meter sidewalk/bicycle track. Therefore, the total width of the bridge, including the outside kerbs (0.5 M x 2), will be 22.5 meters (See ANNEX B-I).

1) Superstructure Plans

This bridge, which will be located in a shore area, is to be built as a concrete bridge, rather than a steel bridge, which will require maintenance against corrosion. Concrete bridges are either a reinforced concrete bridge or a pre-stressed concrete bridge. In consideration of the local work conditions and of economy, a reinforced concrete hollow slab is judged most suitable for this bridge.

The hollow slab will be made by placing concrete around distributed cylindrical forms. Thus, the slab will have a lighter dead weight and require a smaller amount of material than such a slab made otherwise.

Furthermore, this method of slab casting will not require the use of complicated forms and, therefore, will have a high workability. The slab will have a simple and refined appearance.

The advantages of reinforced concrete structures such as bridges can be maximized by using a relatively short span. This bridge will have five 15-meter spans for a total length of 75 meters. It is to be built as a continuous structure, which will promote high quality structural properties and facilitate smooth vehicle operation. Because earthquakes are rare in Tanzania, the superstructure's deadweight inertia in earthquake situations is small, and placing the load on one substructure to avoid in an excessively large structure is known.
Therefore, support conditions have been determined in such a manner that fixed bearings will be on the south abutment, where the pile is the shortest, and all other bearings will be movable. For the high workability and the ease of maintenance, rubber bearings will be used.

Because the superstructure will have a continuous structure, joints need not be made on abutments. However, an expansion joint which will absorb the expansion of the superstructure will have to be installed at the joint with an abutment parapet. As for the south abutment where bearing will be fixed, a gap will be made with a minimum tolerable size to rotation. Since the girders will not expand almost at all, the gap will be filled with elastite. As for the north abutment, an expansion joint will be installed. Since it is estimated that the girders will expand about 20 to 40 millimeters, rubber joints will be used for corrosion resistence and durability.

The superstructure was designed following BS 153 (Part 3A: 1972) of the British Standards Institution for the load, and the Specifications for Highway Bridges of the Japan Road Association for the design method and the allowable stress of materials.

2) Substructure Plans

The project site faces the Indian Ocean with moderate topography and almost no undulations. According to the findings of a geological survey, the site of bridge construction has a thick surface layer of loose sand accumulated over a relatively compacted layer of eroded coral with an interposing layer of fairly compacted coral pieces, under which is a hard

white coral layer. (See ANNEX B-II, and B-III).
Adequate bearing power cannot be expected of the very unstable surface and coral layers, but the lower coral layer, which can support the foundation, is 15 to 30 meters from the ground surface. Therefore, a pile type foundation will be used for this bridge (piles will be steel pipes of ø600 mm). As shallow a substructure bottom slab as tolerable is desirable in order to minimize the excavation quantity, however, in order that the steel piles will be protected against corrosion, the depth of the slab for parts in the sea has been decided at below the level of wave splashing.

Substructure and foundation design has been done in full accordance with the specifications for Highway Bridges of Japan.

4.2 Design Conditions

1) Bridge type : Reinforced concrete hollow slab

2) Bridge length : 75.75 meters

3) Span : 15.0 meters each

4) Effective width:
   Ocean side: 11.5 meters (Carriage way 7.5 M + Pedestrian/Bicycle track 4.0 M)
   Inland side: 7.5 meters

5) Pavement thickness (Asphalt concrete pavement):
   Vehicle lanes: 5 centimeters
   Pedestrian/Bicycle track: 3 centimeters

6) Cross-grade : 2% ↙ ↘ 2%

7) Load: HA load, HB load (45 units)

8) Seismic coefficient: Kh = 0.05

9) Soil coefficient: See Table 4-1

Table 4-1 Soil Conditions

Unit weight	γ = 1.8 t/m^3
Angle of internal friction	ϕ = 30°
Cohesion	c = 0 t/m^2

10) Steel piles corrosion allowance : 2 millimeters

11) Material strength and allowable stress

a) For concrete : See Table 4-2

Table 4-2 Material Strength & Allowable Stresses for Concrete (kg/cm^2)

	Superstructure	Substructure
Design strength at 28 days	240	210
Allowable bending compressive stress	80	70
Allowable shearing stress	3.9	3.6

b) For steel bars (type: SD 30) : see Table 4-3

Table 4-3 Allowable Stresses for Reinforcing Bar (kg/cm^2)

Tensile stresses	(1) Cantilever slab	1,400
	(2) Member in water or under ground water level	1,600
	(3) Others except (1) or (2)	1,800
Compressive stress		1,800

4.3 Design Criteria

The bridge has been designed according to the following standards:

1) BS 153 : Standard for steel girder bridges, 1972
(British Standards Institution)

2) Specifications for Highway Bridges, 1980 (Japan Road Association).

Part 3A: Loads, of the item 1) above was used for load designing, and item 2) above for all other design standards. BS 153, Part 3A: Loads, requires that both HA load and HB load be used for the live load affecting bridges load. HA load consists of equivalent uniform load and knife edge load, and each of these loads for each vehicle lane is stipulated based on the load span. HB load pertains to rarely occuring heavy vehicles: a tractor with a trailer having four axles and 16 wheels is loaded on one lane and 1/3 of HA load is loaded on other lane. HB load is expressed in terms of the number of load units for each axle. The use of 45 units has been decided for this bridge as a result of discussions with the Tanzania Government.

On the sidewalk, a live load capacity of $4KN/M^2$ ($=0.4\ T/M^2$) is planned.

The specifications for Highway Bridges consists of five sections. Each of the Sections used for the bridge project is summarized bellow.

I. General :	Covers load, materials, and bridge accessories (however, the "load" part was not used, because BS 153 was used)
III. Concrete Bridges;	Covers the design estimation of concrete bridge, allowable stress, structural details, floor slab, various bridge styles, and work execution.
IV. Substructure:	Outlines the investigations, designing, and work execution for substructure, including foundation.

V. Aseismic Design : Defines structural designs for various seismic intensities (coefficients).

The factors are taken into consideration as the impacts of earthquake on structures are:

a) Own inertia.

b) Deadweight inertia.

c) Earth pressure in earthquake condition.

d) Dynamic water pressure in earthquake condition.

4.4 Superstructure Design

1) Load

a) Dead Load

The dead loads to be taken into consideration in the design of this bridge include:

i) Main slab deadweight.

ii) Pavement.

iii) Sidewalk material.

iv) Handrails, wheel guard and kerbstone.

v) Additives.

The unit dead weight of the materials have been adapted as shown in Table 4-4.

Table 4-4 Unit Weight of Materials

Material	Unit Weight (kg/m^3)
Steel, cast steel	7,850
Aluminum alloys	2,800
Reinforced concrete	2,500
Plain concrete	2,350
Sand, crushed stone	1,900
Bitumen	2,300

Additives have been adapted at 100 kilogram-weight per metter of bridge length.

b) Live Load

i) Number and width of Vehicle Lanes

The number of vehicle lanes is determind by the carriageway width (see ANNEX B-V). Because the carriageway includes the shoulder and the marginal strip, the number and the width of vehicle lanes have been determined as presented below :

Carriageway width	:	7.50 meters
No. of lanes	:	3
Width of lanes	:	2.50 meters

ii) HA Load

Because this bridge will have 15-meter spans, the equivalent uniform load per meter of one vehicle lane in the proceeding direction is given from the table (ANNEX B-IV) as 31.5KN/M (= 3.15 t/M). Likewise, line load per unit of width is given as 40 KN/M (=4.0 T/M).

For consideration of the greatest disadvantage to the member, these HA loads were all placed on two vehicle lines adjacent to each other, and only 1/3 of them were placed on the remaining lanes.

iii) HB Load

HB load axles are distributed as shown in ANNEX B-VI. For this bridge, load per each axle is adopted as 45 unit (≑ 450 KN = 45 T), which corresponds to 112 KN (≑ 11.2T) per wheel.

HB was loaded on only one lane, which is the maximum disadvantage to the member, and 1/3 of the HA load was placed on other lanes.

It is allowable that 25% higher stress is used for the checking of stress of members under HB load.

iv) Sidewalk Live Load

Sidewalk live load is adopted at W = $4KN/M^2$ (= $0.4 T/M^2$) in accordance with BS 153, Part 3A, 4. The sidewalk of this bridge will include a bicycle track and a plant belt, but sidewalk live load was placed on the entire width of the sidewalk.

2) Loading Method

The method of loading a live load is illustrated in Fig. 4-1.

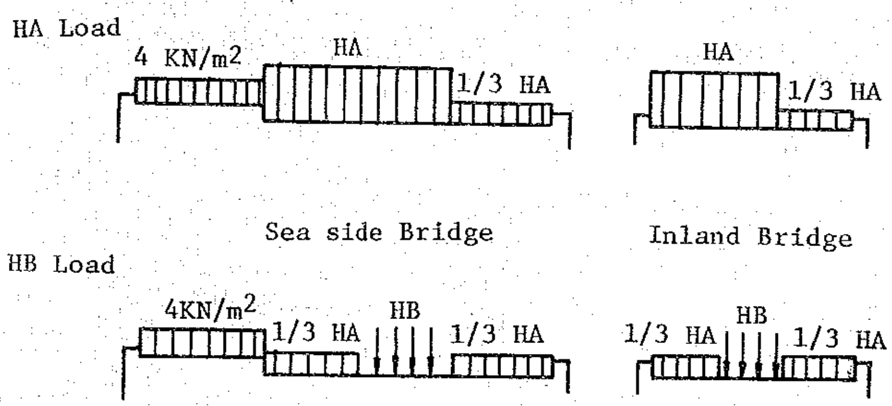


Fig. 4-1 Loading

3) Design Calculation

Structural analyses and stress calculations for superstructure were carried out by mainly using electronic computer. The processes and resultants are described in the separate volume "Design Calculation".

4.5 Substructure Design

1) Loads Affecting Substructure

Following are the loads which will affect the substructure:

a) superstructure dead load reaction, b) superstructure live load reaction, c) body deadweight, d) covering soil, e) over-superimposed load, f) earth pressure (normal and seismic), g) buoyancy, h) inertia in earthquake situations, i) dynamic water pressure, and j) horizontal reaction by superstructure expansion (due to temperature changes).

Stability was calculated and cross section stress checked for normal and seismic conditions and in temperature changes by the combination of these loads.

2) Substructure Design

As the substructures are of a wall type, the sectional forces are calculated as cantilever for the application of loads of item 1) above. The results of sectional force and stress calculations are shown in Table 4-5.

Table 4-5 Sectional Forces and Stresses of Piers and Abutments

		Unit	A_1	P_3	A_2
Axial force		t	21.8	205.1	15.4
Bending moment		t.m	4.5	45.8	12.3
Shearing force		t	3.1	12.1	8.6
Reinforcement	Diameter & pitch	mm	D16 - 300	D16 - 300	D16 - 300
	Area	cm^2	6.63	13.90	6.63
Bending stresses	Concrete	kg/cm^2	*	*	9
	Reinforcing bar	kg/cm^2	*	*	334

Force are per 1 m width for Abutments
* Negligible

4.6 Foundation Structure Design

1) Allowable Bearing Capacity of Piles

The ultimate bearing capacity of the piles was calculated based on the soil condition at the bottom tip of the piles and friction around the piles, as revealed by a geological survey. The allowable bearing capacity was determined by dividing the ultimate bearing capacity by the required safety factor (see Table 4-6).

Table 4-6 Bearing Capacity of Piles

(t)

		A_1	P_3	A_2
Ultimate bearing capacity		289	266	320
Allowable	Normal condition	96	89	106
	Seismic condition	145	133	160

(Safety factor : Normal c = 3, Seismic c = 2)

2) Calculation of Bearing Power of Piles

Forces affecting the bottom of the footing were calculated under the combination of loads listed in Section 4.5, item 1), above, including calculation of the driving (or pulling) force, bending moment, and horizontal force which work on each pile (see Table 4-7)

Table 4-7 External Forces for a Steel Pipe Pile

		A_1	P_3	A_2
Normal condition	Axial force (t)	80.4	82.3	72.0
	Bending moment (t.m)	8.8	-	4.9
	Shearing force (t)	7.0	-	7.6
Seismic condition	Axial force (t)	71.3	83.8	77.0
	Bending moment (t.m)	9.0	4.4	10.0
	Shearing force (t)	9.7	3.4	18.6
Temperature change	Axial force (t)	83.5	108.1	72.0
	Bending moment (t.m)	9.5	5.6	3.6
	Shearing force (t)	8.9	7.8	9.2

CHAPTER 5

ROAD DESIGN

CHAPTER 5. ROAD DESIGN

5.1. Design Principles

This chapter describes the detailed design work for the required road upgrading through the installation of additional vehicle lanes and the improvement of approach roads to the Selander Bridge and adjacent Junctions in order to secure efficient, safe, and smooth flow of traffic on the 1.2-kilometer long section (See ANNEX C-I).
The discussions with Tanzanian officials have resulted in an agreement that the Japanese Highway Design Standards be used in the design of this project. The basic design principles are as follows.

1) Future Traffic Volume

The planned roads were classified by traffic volume and topographical and other conditions of the area adjacent to the road projected in the target year (1990). In addition to the traffic volume surveys which had been conducted by the Tanzanian Government, the Preliminary Study Team from Japan made actual traffic count surveys in peak hours.

Using these survey findings and taking into consideration the Dar es Salaam City Development Programme, the southward bound traffic volume was estimated for the target year at 3,000 passenger car equivalents per peak hour (See ANNEX C-IV for analysis results). As indicated by the 1970 survey, 30% has been used as the rate of right turn traffic to total southward bound traffic at the West Junction, which is and will in the future be a traffic bottleneck, assuming that the traffic pattern at this Junction has little changed since 1970 and will change little in the future.

The 1970 survey by the Tanzanian Government indicated a traffic volume of 38,700 vehicles in 12 hours (7:00 A.M to 7:00 P.M) in both directions and of 1,277 vehicles in the peak hour (7:00 to 8:00 A.M) at the Selander Bridge (See ANNEX C-IV). The indicated magnitude of traffic makes this road a Category 4, Class 1 road by the Japanese Standards (design standard traffic of 10,000 vehicles per lane per day in urban areas).
Therefore, Category 4, Class 1 standard will be used for the detailed design of this road.

2) Design Speed

A design speed of 60 kilometers per hour by the Japanese Standards for Category 4, Class 1 roads will be used. The same design speed needs not be used for junctions, where vehicles decelerate, stop, and then accelerate. In Japan, it is acceptable that, for Category 4, Class 1 roads, a 20 k.p.h lower design speed be used for junctions than the design speed for roadway. Accordingly, a design speed of 40 kilometers per hour will be used for the Junctions in the project area. The use of a low design speed for junctions is desirable from safety and traffic flow standpoints, inasmuch as the use of a lower design speed enables the use of a smaller radius of curvature near the vehicle stopping line, which, in turn, forces vehicles to approach the stopping line with a slower speed.

Assuming that at junctions vehicles decelerate at the rate of 3.0 m/sec^2, stop, and then accelerate at the rate of 1.5 m/sec^2, the following equation describes the relationship:

$$L = \frac{1}{26\alpha}(V^2 - V_o^2) \quad \text{..........} \quad (5.1)$$

Wherein: L = Running distance (meter)

α = Acceleration/deceleration speed (m/sec^2)

Acceleration speed = 1.5 m/sec^2

Deceleration speed = −3.0 m/sec^2

V = Final speed (kilometer/hour)

V_o = Initial speed (kilometer/hour)

The relationship between speed and running distance as calculated by this formula is shown in Fig. 5-1.

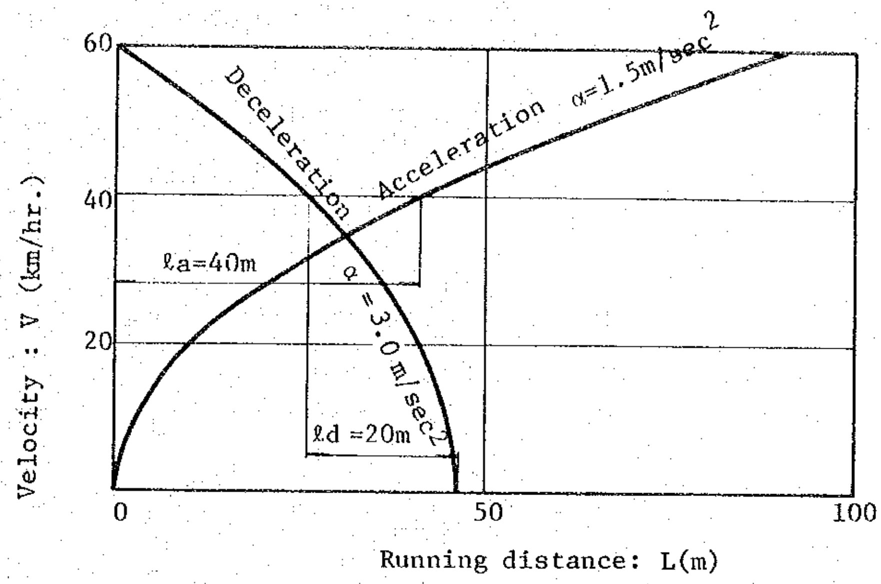


Fig. 5-1 Relationship between Acceleration/Deceleration Speed and Running Distance

By this relationship, vehicles running at the speed of 40 kilometers per hour would require a distance (ℓd) of about 20 meters in order to decelerate and stop, and stopped vehicle would require a distance (ℓa) of about 40 meters to reach the speed of 40 kilometers per hour. Thus, the design speed of 40 kilometers/hour is used for the distance of about 20 meters before (approaching) and after (leaving) junctions.

5.2 Design Standards

1) Geometric Design Standards

Geometric Design Standards for various design speeds are shown in Table 5-1.

Table 5-1 Geometric Design Standards

	Design Speed	60 km/hr	40 km/hr
Horizontal alignment	Min. Radius of curve	150 m	60 m
	Min. Horizontal curve length	100 m (700/*θ)	70 m (500/*θ)
	Min. Transition curve length	50 m	35 m
	Min. Clothoide parameter	90 m	50 m
Super-eleva-tion	Max. Superelevation	5 %	7 %
	Max. Superelevation variation	1/125	1/100
Vertical alignment	Max. Gradient	5 %	7 %
	Min. Vertical curve (Crest)	2000 m	700 m
	Min. Vertical curve (Sag)	1500 m	700 m
	Min. Vertical curve length	50 m	35 m
	Max. Compound gradient	8 %	8 %

*θ : Intersection angle

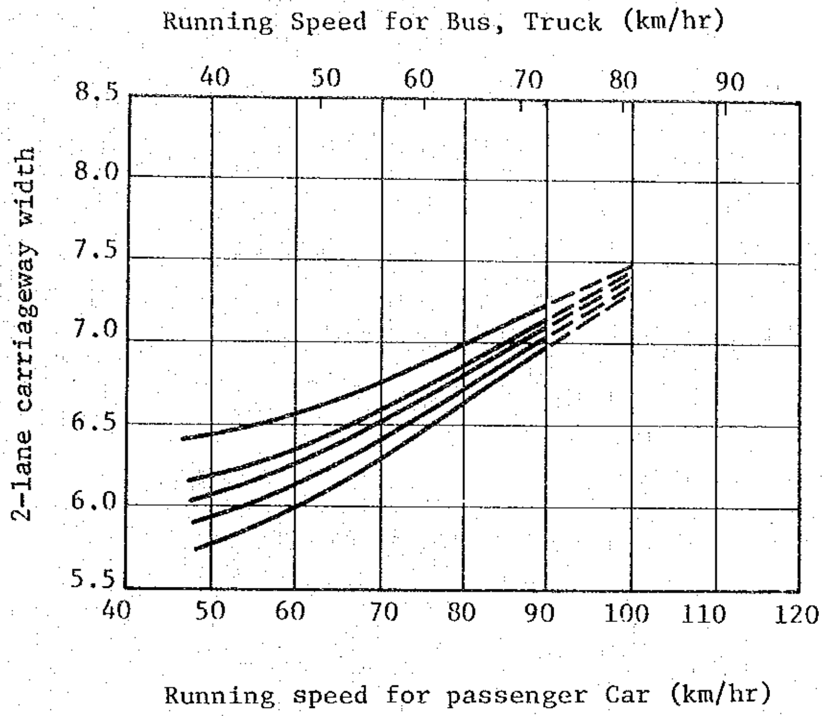
2) Cross Section

Ordinary sections of the road will have the following cross section:

	Width (meter)
Carriageway (4-lane)	13.0
Shoulder (0.75 meter x 2)	1.5
Sidewalk and bicycle track (3.0 meter x 2)	6.0
Median strip	3.0
Planting strip (1.0 meter x 2)	2.0
Total effective width :	25.50

(a) Carriageway

Vehicle lanes must have a sufficient width with a margin for the safety of passing and crossing, but not an excessive width which permits three rows of vehicles in the same direction to form on a two-vehicle lane road, which, when occurs, is quite hazardous and can result in traffic accidents. The optimum vehicle lane width was determined based on the maximum width of vehicles (2.5 meters) and safety margin, dependent upon vehicle running speed and traffic volume. The relationship between vehicle operating speed on 2-lane carriageways and lane width in Japan is graphically presented in Fig. 5-2.



P : Share of the total of buses and trucks in ADT (%)

Fig. 5-2 2-lane Carriageway width Determined in Operating Speed Experiments in Japan

It is noted in Fig. 5-2 that 2-lane carriageway must have a width of 6.0 to 6.5 meters (3.0 to 3.25 meters per lane) in order that passenger cars can be operated safely at the speed of 60 kilometers/hour.

In veiw of the heavy traffic existing in the project area, the lane width of 3.25 meter is adapted for this project.

(b) Number of Vehicle Lanes

In view of the fact that traffic is already heavy, that the traffic volume estimated for the target year is 38,700 vehicles per day, and that the basic traffic volume for Catergory 4, Class 1 roads is 10,000 to 12,000 vehicles per day, it has been decided that the roads will be given two vehicle lanes in each direction, a total of four lanes.

(c) Median Strip

In the case of roads with four or more vehicle lanes, safe and smooth vehicle operation is facilitated by separating traffic moving one direction from that moving in the other by the installation of a median strip. In addition, a median strip will provide space for the installation of road signs and other traffic control facilities, it is claimed that median strips with a greater width have greater benefits. Furthermore, a median strip having a width comparable to that of the vehicle lane can be converted into an additional lane where a right-turn traffic lane needs to be added without adversely affecting the alignment of straight traffic lanes at junctions.

In view of the fact that the project road will become a representative part of the arterial road running through Dar es Salaam City, that right-turn lanes are needed at junctions for the smooth flow of the heavy traffic, and that the alignment of the main lanes needs to be shifted near junctions, it has been decided that the width of the median stip will be three meters.

5.3 Alignment Design

1) Horizontal Alignment

The horizontal alignment of the project road and access road has been determined as follows: (a) for the beginning and ending points of the project route, the alignment was determined in such a manner that the project road center will coincide with the existing road center, (b) for the bridge, the alignment was determined in such a manner that there will be a distance of at least one meter between the new bridge and the existing bridge for the reasons of cofferdam and workability, and (c) in the vicinity of STA. 1 + 00 to 3 + 00, where various nations' embassy buildings are located, STA. 8 + 50, where the police station is located, and of private houses, the

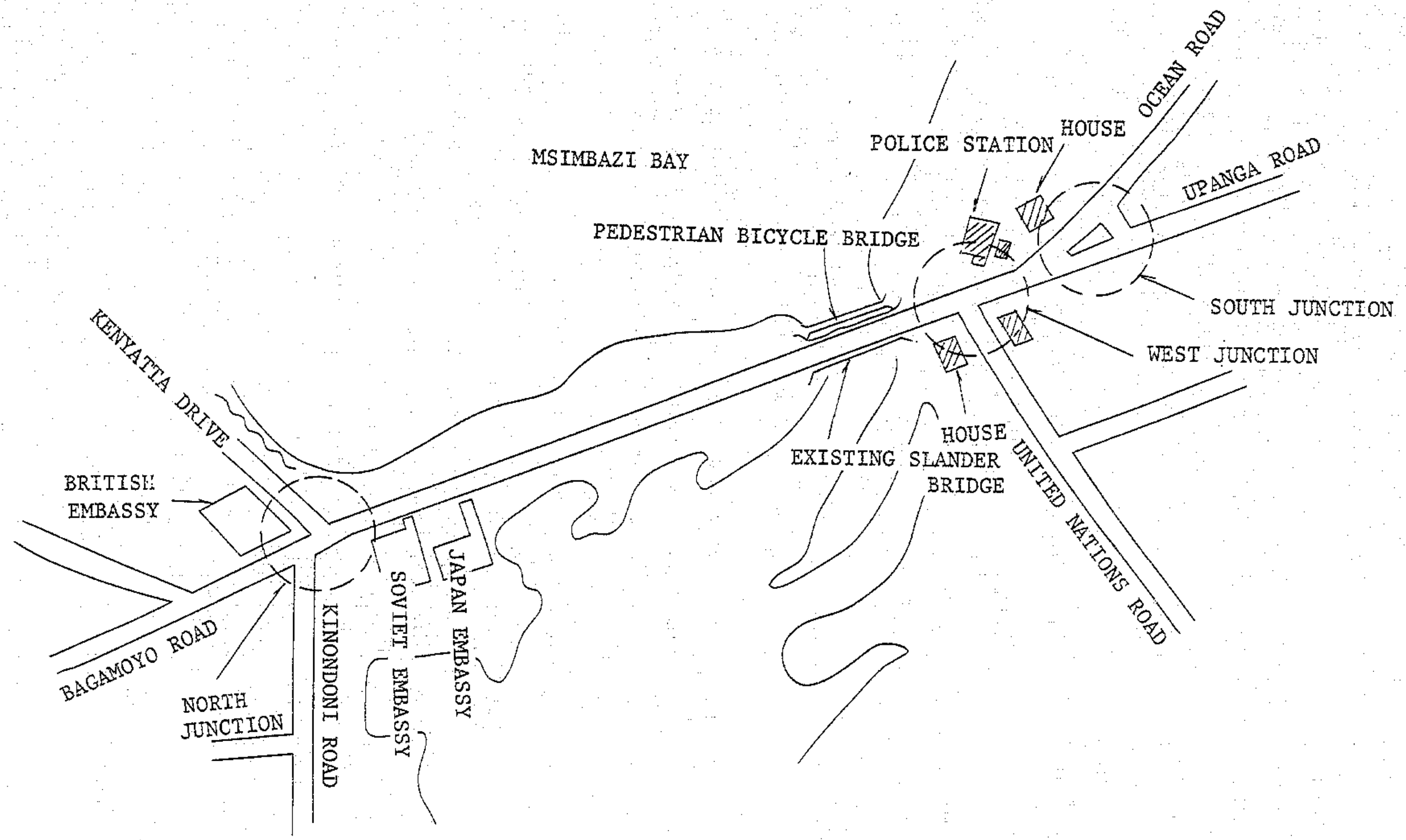


Fig. 5-3 Map of control points for determination of alignment

alignment was decided in such a manner that the road will not go through any part of their premises. In addition, efforts were made to use as large an alignment as possible in order to secure an adequate sight distance, because the project route contains three junctions. For the purpose of creating additional two lanes for exclusive use by vehicles coming off the Selander Bridge and making right turn at West Junction, it was contrived so that the requirements for traffic induction will have no affect on the Bridge.

It has been recommended that the clothoide parameter (A) of the transition curve to be inserted between circular curves have the following relationship with the curves :

$$R/3 \leqq A \leqq R$$

Wherein : R = Radius of curve (meter)

A = Clothoide parameter (meter)

However, this relation is applicable only when the radius of circular curves remains within a certain scope; when the radius (R) is small, the parameter (A) becomes larger than the radius (R), (A) becomes smaller than (R/3) when the radius (R) is large. Generally, and a combination along the curve shown in Fig. 5-4 is recommended from the standpoint of alignment harmony, driver benefit, and economy.

Also, when the shift in volume from straight line to circular curve is sufficiently small in relation to the margin of lane width, direct connection of the straight line with the curve will cause no difficulty to vehicle operators as the shift is adequately covered by the lane width.

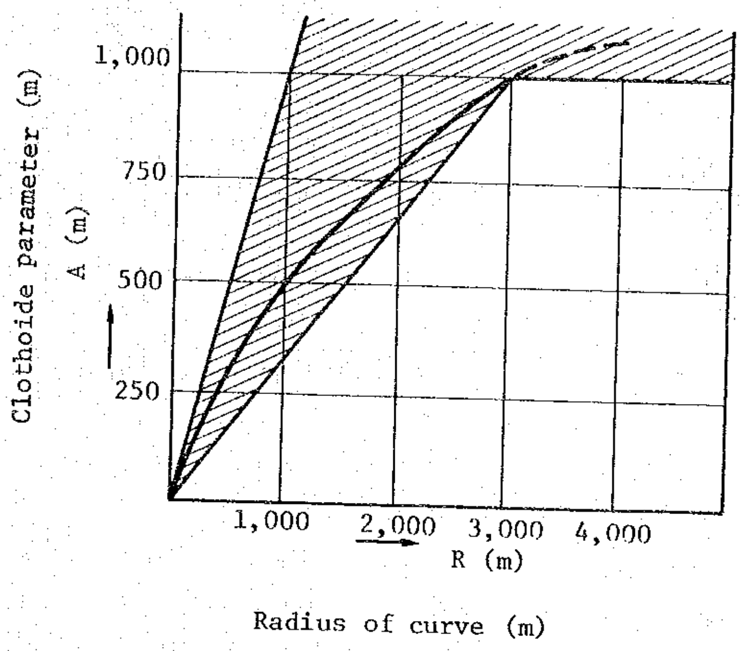


Fig. 5-4 Relationship between Radius of Curve and Clothoide Parameter

The boundary shift for the decision of whether or not a transition curve be inserted between a straight line and a circular curve is about 20 centimeters. So, if a transition curve is to be used when the shift is over 20 centimeters,

$$S = \frac{1}{24} \cdot \frac{L^2}{R} \quad \cdots\cdots\cdots\cdots \quad (5.2)$$

Where : S = Shift (meter) = 0.20 meter
L = Clothoide curve length (meter)
R = Radius of curve (meter)

Also, the required transition curve length is:

$$L = \frac{V}{3.6} \cdot t \quad \cdots\cdots\cdots\cdots \quad (5.3)$$

Where : V = Vehicle speed (km/hour)
t = Running time required for the manipulation of steering wheel.

From the equations 5.2 and 5.3

$$\left(\frac{V}{1.2}\right)^2 = 4.8R$$

Therefore, $R = 0.144\ V^2$

Insert design speed (V = 60 km/hour)

$$R = 0.144 \times 60^2 = 518 \text{ (rounded to 500 meters)}$$

It is desirable that a transition curve of about double the above value be inserted in order to secure driver benifit both from vehicle operation and visual standpoints. Therefore, it has been decided that a clothoide curve is to be inserted up to R = 1,000 meters and that no clothoide is to be inserted when (R) is in excess of 1,000 meters.

2) Vertical Alignment

The project road to be constructed in flat land requires few control points for its vertical alignment planning. The first of the control points that can be mentioned is the clearance under the new Selander Bridge. In order that the clearance will not be smaller than the under-the-girder height of the existing bridge (3.06 meters, as physically surveyed: the existing bridge CH 3 + 53.2 corresponds to the position of the new bridge, STA.7 + 45.5), the vertical alignment has been determined so as that it will not be less than 4.41 meters (the 3.06 meters + 1.35 meters for the girder height, slab depth, and effective height).

Next, in order not to spoil the existing ease of movement (access) between the existing road and the Embassy buildings, the police station and private houses, which are currently about on level with each other, the vertical alignment has been decided in such a manner that, with an overlay of about 10 centimeters, the new road will also be as closely on level with these buildings as possible.

Also, at North, West, and South Junctions, in order that the vertical plan of access roads will be as moderate as possible, the vertical alignment has been decided in such a manner that the new road will be 10 centimeters higher than the existing road. (See ANNEX C-II which is a profile)

5.4 Earthwork Design

Since this Project involves a road built in flat land, the earthwork quantities for the road upgrading are very small--cutting depth and embankment height will be one to two meters in almost all cases.

Soil and material investigations have shown that the soil found in the project area is adequate for use as embankment material. Based on the soil investigation findings and in consideration of the cutting depth and the embankment height, the following gradients have been determined.

Gradient of embankment slope = 1 : 1.5
Gradient of cutting slope = 1 : 1.0

The median strip will be a mountable type, filled with soil and sodded. The margin between sidewalk and vehicle lane and training islands will also be filled with soil, sodded, and, in this case, planted with trees in the absence of side clearance problems.

2) Slope Protection

Earthwork slopes will be sodded for both appearance and protection against erosion. Because the earthwork material is a highly erosive soil, sodding will be done in a blanket fashion immediately after the finish of earthwork and a sufficient amount of pins will be used to hold the sod in place. The sodding of embankments will receive a thin layer of sprinkled fertile soil for protection against excessive drying. In the area near South side abutment (that is, in the vicinity of STA.7 + 47 to STA.7 + 70), a riprap slope will be used for complete protection against erosion.

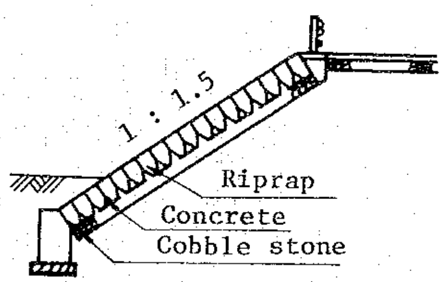


Fig. 5-5 Rock Riprap

5.5 Drainage Design

The carriageway surface will have a convex cross section with L-shaped side ditches at each end. Water will be drained from an L-shaped gutter, through a grating lid, into a catch basin below at the intervals of about 30 meters and then, drained out of the road by drain pipes. Sidewalks/ bicycle tracks will have a down slope toward the outer edge and be naturally drained over the protective shoulder without the use of any drainage structures. As a principle no side ditches will be installed at the embankment slope shoulders and cut slope shoulders. Drainage facilities will not cross underneath the carriageway unless it is absolutely necessary to do so, in which case, box culverts (450 mm x 450 mm) will be used.

1) Flow Calculation

The following equation is used for calculating the quantity of flow in order to determine the cross section of drainage structures:

$$Q = \frac{1}{3.6 \times 10^6} \cdot C.r.a$$

Q : Quantity of flow (m^3/sec)

C : Run-off coefficient

r : Design rainfall intensity (mm/hr)

a : Drainage area (m^2)

The run-off coefficient (C) depends on the kind of ground surface. In the case of asphalt paved road surface, C = 0.9, and in case of slope, it is about C = 0.6. The design rainfall intensity (r) is the value which is determined by the local precipitation behavior, and in the case of this Project, r = 65 millimeters will be used based on the rainfall data.

Therefore,

$$\text{Road surface run-off} = \frac{1}{3.6\text{x}10^6} \text{ x } 0.9 \text{ x } 65 \text{ x a} = (1.625 \text{ x } 10^{-5}) \text{ x a } (m^3/\text{sec})$$

$$\text{Slope surface run-off} = \frac{1}{3.6\text{x}10^6} \text{ x } 0.6 \text{ x } 65 \text{ x a} = (1.083 \text{ x } 10^{-5}) \text{ x a } (m^3/\text{sec})$$

2) Discharge Capacity

The discharge capacity of side ditches is calculated as follows:

$q = v.a$

q : Flow capacity (m^3/sec)

A : Flow area (m^3)

v : Velocity (m/sec)

$= \frac{1}{N} \times R^{2/3} \times I^{2/1}$

R : Hydraulic mean depth

I : Gradient

N : Roughness coefficient = 0.015

Therefore,

L-ditch capacity = $0.078 \times I^{1/2}$ (m^3/sec)

U-ditch (300mm x 300mm) capacity = $1.290 \times I^{1/2}$ (m^3/sec)

Box culvert (450mm x 450mm) capacity: $3.816 \times I^{1/2}$ (m^3/sec)

The intervals at which grating lid is to be installed and the location of outlet can be determined based on the above capacities.

See ANNEX C-VI for the cross section and dimensions of side ditches.