LINK ROAD
BETWEEN
MALTA AND GOZO ISLANDS

PRELIMINARY SURVEY REPORT

MARCH 1979

OVERSEAS TECHNICAL COOPERATION AGENCY
GOVERNMENT OF JAPAN

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FOREWORD

In compliance with the request of the Government of Malta, the Government of Japan agree to extend its assistance in the road construction project which connects Malta Ild., Comino Ild., and Gozo Ild., and entrusted the Overseas Technical Co-operation Agency with its execution.

The Agency, having full congnizance of the necessity for Malta to construct th this connection road, organized a five-men team headed by Mr. Yoshimaro Matsuzaki, Manager of Planning Development Department of Honshu Shikoku Bridge Public Corporation, and despatched it Malta for a field survey which lasted from December 1, 1971 to December 19, 1971.

The report hereby presented has been compiled on the basis of the findings of the field survey.

It would give me a great pleasure if this report should serve to accelerate the development this construction project and at once enhance the amity between Malta and Japan.

I avail myself of this opportunity to express my heartiest gratitude to the competent Malta authorties, for their unlimited assistance and cooperation which were most valuable in the execution of survey activities.

March 1972

Keiichi Tazuke
Director General
Overseas Technical Cooperation Agency

CONTENTS

1. Introduction

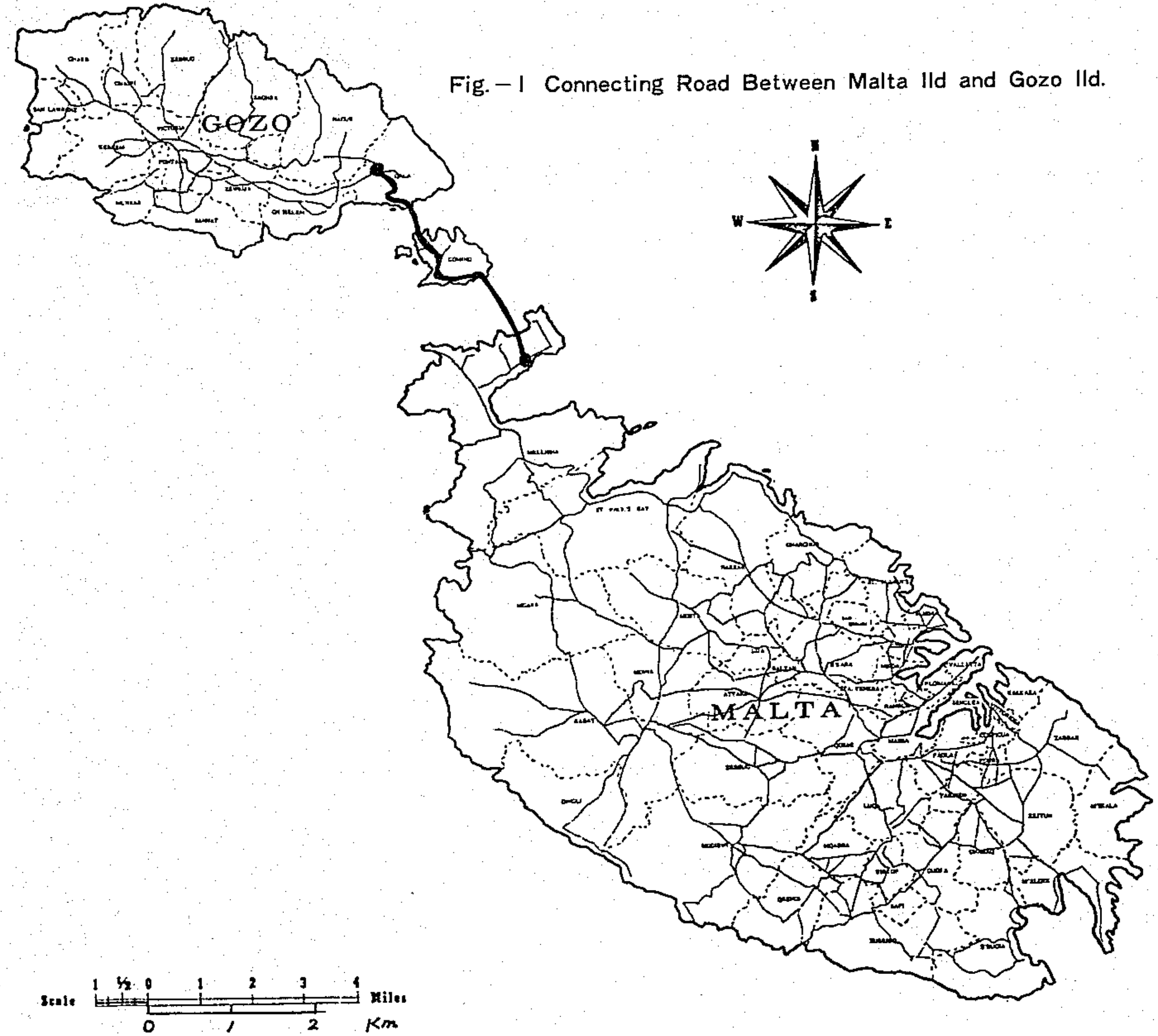
A preliminary survey was conducted for the construction of a link road across the channels between Malta and Gozo in Malta, for twenty days from December 1st to 20th, 1971. The object of the survey was to examine the technical feasibility of the link road construction, and a comparative study of methods for constructing the road over the channels was also made along with the estimation of construction cost, as requested by the Government of Malta.

The general situation of the proposed construction site is as shown in Figure 1, and the road will connect Malta and Gozo which face each other across the channels with Comino lying between them. If the two islands are to be linked through Comino each length of road sections over the South and North Comino Channels is respectively about 1.8 km and 1.0 km, while it is about 5 km by direct linking. The south channels has the maximum depth of water of about 24 meters and the north channel about 20 meters and it is said that a tide runs eastward at the maximum speed of 1 knot. At present, car-ferries are operating between the islands.

In view of the actual examples of such construction in other countries, the channel does not present very serious difficulties for constructing the proposed link road. As construction works in the sea are attended with much more difficulties compared with those on the land, detailed surveys are required on the topography and geology across the channels, tidal current, wave, and climatic condition in order to determine the construction method and to estimate the construction cost. However, the data available at present on these matters for the proposed site are very few so that we were compelled to prepare the report on the basis of such inadequate information. The report is to present our opinion fixed for the present time to compley with the strong wish of the Government of Malta, though the final conclusion should be drawn based on the results of detailed investigations in the future.

In constructing the link road across the channel a thorough examination should be made for the effect on the environmental protection, especially in view of the area being' a valuable tourist resort in Malta. Since no precedent is found for the construction of link road over the channels through the island lying in the open sea, many difficulties are expected to occur in judging the effects of the structure on the tide and the topography across the channels.

Fig. — I Connecting Road Between Malta IId and Gozo IId.



The constitutents of the Survey Team were as follows:

Chief	Yoshimaro MATSUZAKI	Honshu-Shikoku Bridge Authority
Member	Yasuhiro KIMURA	Tokyo Expressway Public Corporation
"	Shigenori ONO	Road Bureau, Ministry of Construction
"	Keiichi KOMADA	Road Bureau, Ministry of Construction
"	Hirohiko TADA	Honshu-Shikoku Bridge Authority

During our stay in Malta we had the honor to meet Mr. Dominic Mintoff, the Prime Minister, including Mr. A. V. Hyzler, the Minister of Development, and Mr. Lorry Sant, the Minister of Public Building and Work and could know their personal opinions on the planning of link road which gave us many useful suggestions. We express our sincere gratitude to the persons concerned of the Government of Malta who rendered us much assistance for our activities.

2. Conditions in Planning and Carrying Out of Works.

2.1 Topography

The Maltese Islands consisting of three main islands of Malta, Gozo and Coni Comino are situated approximately in the center of the Mediterranean Sea, lying between 35°47' and 36°5' of north latitude and between 14°10' and 14°35' of east longitude. It is at a distance of 58 miles (93 km) from Sicily of Italy and about 180 miles (246 km) from Tunisia of Africa.

Malta has an area of 95 square miles (246 km^2) and the areas of Gozo and Comino are respectively 26 square miles (67 km^2) and 1 square mile (2.6 km^2). All islands are gently sloping tablelands and the highest point is 846 feet (262 m) above the sea. In the northwest of Malta, several falts run nearly at right angles to the longitudinal axis of the island, forming the channels which separate Malta, Gozo and Comino. The difference of the beds due to the faults is about 400 feet (120 m).

The width of South Comino Channel between Malta and Comino is about 1.8 km and that of North Comino Channel between Comino and Gozo is about 1.0 km. The maximum depth of water in South Channel is about 24 meters and that in North Channel is about 20 meters.

As for the topography of land, the channel side of Malta is a gentle slope in contrast to a steep cliff of Gozo which requires to insert a curve in the access road to treat the longitudinal slope. Comino is a low flat tableland.

2.2 Geology

The Maltese Islands are composed of the limestone of the tertiary period lying in five different strata, of which the typical strata are of coralline limestone and globigerina limestone.

The globigerina limestone lies over the surfaces of the east sise of the great fault in Malta and of the western half of Gozo; in the vicinity of the channle, the coralline limestone stratum which is the third upper layer above the globigerina limestone stratum outcrops due to the fault. The geological map of the channl is shown in Figure 2.

The upper coralline limestone is composed of hard white limestone and soft porous limestone. Though the details of geology for the channel are not known because no record of boring is avilable, the sea-bed seems to be covered with the uper coralline limestone to consitute a satisfactory foundation for structures. The globigerina limestone is a soft yellow sandstony limestone which has been widely used as building material from the ancient times in Malta.

2.3 Meteorology

The meteorology of the Maltese Islands represents the typical Mediterranean climate. It is dry in summer and mild and wet in winter. It scarcely rains from May to August and the rain comes on chiefly between September and April, with the annual precipitation being about 590 mm. There is almost no snowfall but some hail for about 9 days per year. Fog sets in for about 11 days per annum, rather frequently between February and May. The hours of daylight are about 5.4 hours in December and about 12.3 hours in July, with the annual average being 8.5 hours per day. The annual mean temperature is about 19°C.

Comfortable northwest wind prevails and northwest gale blows around the times of vernal and autumnal equinoxes, with southwest gale prevailing in Summer. Fig. 3 shows the direction and frequency of gale having the mean wind speed of 22 knots (11.4 m) or more recorded at Luqa Airport for 10 years from 1958 to 1967.

The records of meteorological observation at Luqa Airport are shown in Tables 1 and 2.

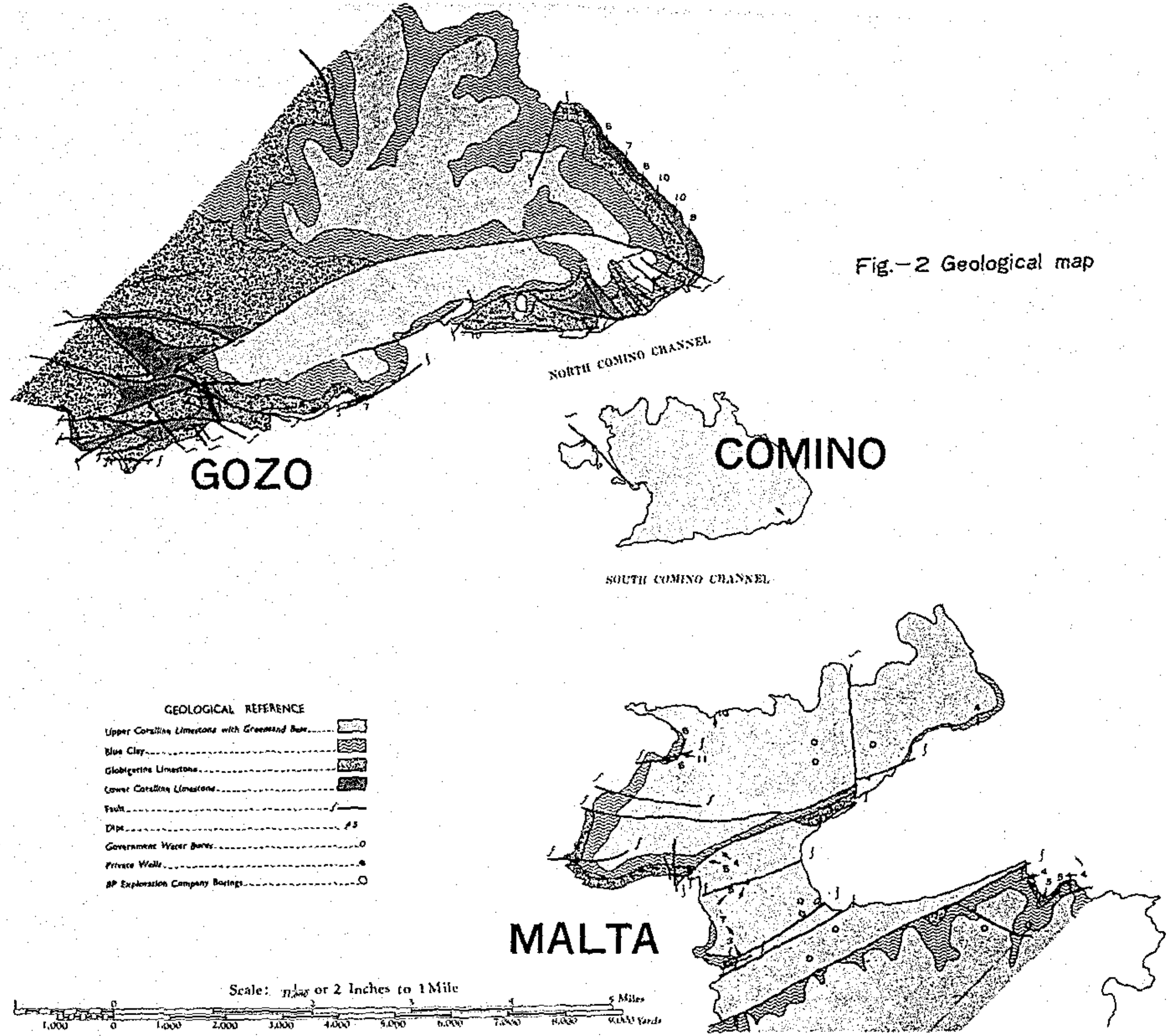


Fig.-2 Geological map

Fig.—3 Wind-direction Diagram

(For the above 22 knots average wind velocity.
1958～1967, p.m.1:00, at Luqa)

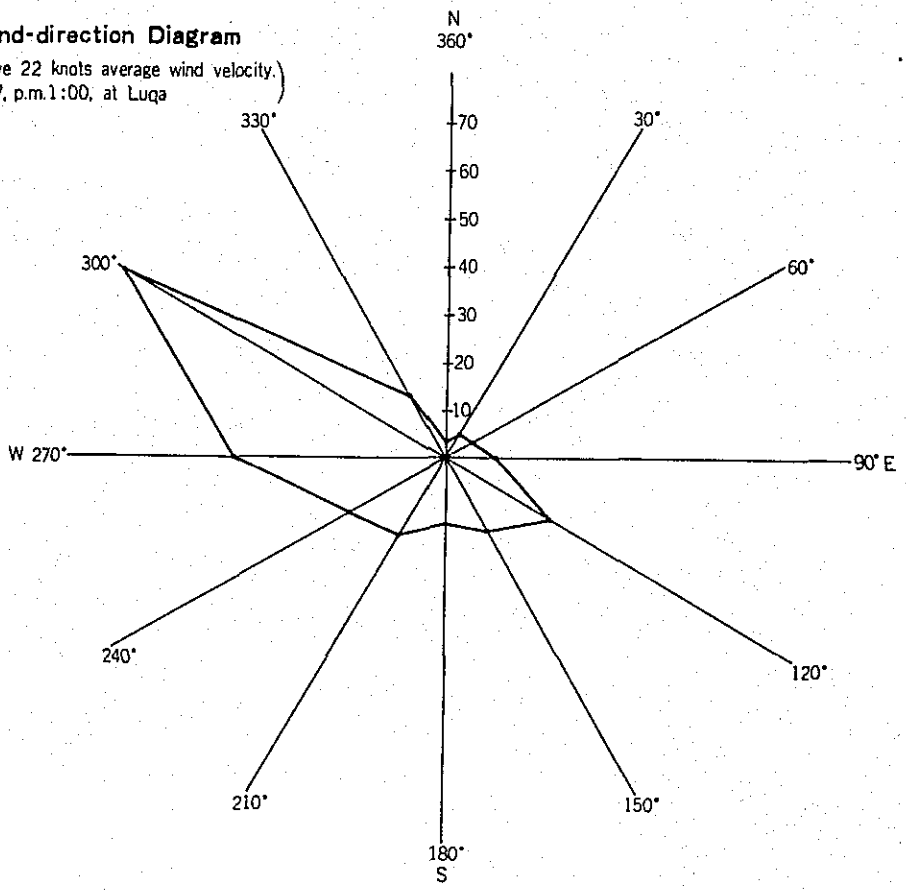


Table 1-(1) General Climatological Tables - LUQA, Malta
Period of Observations 1947 - 1966

	Pressure Mean Sea Level MB.	Temperature °C						Rainfall mm					Sunshine Hours per Day	Mean Monthly Sea Temp. °C
		Mean Monthly	Mean Daily Maximum	Mean Daily Minimum	Average Highest	Average Lowest	Extreme Highest	Extreme Lowest	Mean Monthly	Wettest Month	Driest Month	Average No. of Days 0.1 mm or more		
January	1016.3	12.3	14.9	09.7	18.7	05.0	21.2	01.5	90.6	163.6	27.8	15.1	5.52	14.3
February	1016.5	12.3	15.3	09.4	19.7	05.1	26.7	01.7	51.9	187.9	3.5	10.3	6.55	13.8
March	1015.9	13.5	16.6	10.4	22.1	05.9	28.9	02.2	40.7	144.6	1.0	8.6	7.51	14.1
April	1015.4	15.5	19.1	12.0	24.1	07.8	28.3	04.4	25.1	113.3	Trace	5.7	8.60	15.3
May	1015.2	19.0	23.0	15.1	28.7	11.4	33.3	09.7	8.7	39.4	Trace	2.9	10.12	17.6
June	1015.9	23.2	27.6	18.9	33.1	15.6	37.2	13.3	3.1	19.3	Nil	1.1	11.59	21.3
July	1015.0	25.9	30.3	21.5	35.6	18.8	41.0	16.1	1.4	18.0	Nil	0.4	12.34	24.4
August	1015.0	26.3	30.5	22.0	35.0	19.1	38.3	17.2	12.0	155.5	Nil	1.2	11.59	26.1
September	1016.9	24.2	27.8	20.6	31.9	16.8	36.7	15.0	32.3	163.0	Trace	3.9	9.28	25.0
October	1016.8	20.8	23.9	17.6	28.4	12.8	30.6	10.6	139.7	476.5	29.1	10.9	7.27	22.5
November	1016.7	17.2	20.1	14.2	25.7	09.3	26.7	06.1	92.0	237.0	6.2	11.4	6.42	19.4
December	1016.3	13.9	16.6	11.2	20.8	06.9	24.3	05.6	89.3	188.5	46.9	14.1	5.37	16.4
Year	1016.0	18.7	22.1	15.2			41.0	01.5	586.8			85.6	8.51	19.2

Table 1-(2) General Climatological Tables - LUQA, Malta (Page 2)

Average Number of Days with	Snow	Hail	Thunderstorms	Fog	Gales (Wind Beaufort Force)	Wind Gusts 34 Kt or More	Relative Humidity Mean %				Vapour Pressure MB.			
							03Z	09Z	15Z	21Z	03Z	09Z	15Z	21Z
January	0.1	2.7	2.4	0.4	0.2	6.2	81	75	73	80	10.9	11.6	11.3	11.1
February	0.0	1.8	2.2	1.5	0.1	6.8	83	74	70	83	10.7	11.1	11.0	11.0
March	0.0	0.8	1.3	1.4	0.0	7.1	83	71	69	81	11.3	11.8	11.6	11.6
April	0.0	0.0	1.3	1.6	0.0	5.9	85	67	66	83	12.9	13.0	12.9	13.5
May	0.0	0.0	1.1	1.5	0.0	3.3	86	62	60	82	15.5	15.1	15.0	16.1
June	0.0	0.0	0.7	1.0	0.0	1.6	81	57	53	77	17.1	16.3	17.3	19.2
July	0.0	0.0	0.2	0.7	0.0	1.2	81	57	55	77	22.3	21.7	21.6	23.3
August	0.0	0.1	1.3	0.5	0.0	0.5	81	59	57	79	22.8	22.6	22.3	24.0
September	0.0	0.2	2.3	0.2	0.0	1.0	84	64	64	80	21.3	21.2	21.3	22.1
October	0.0	0.4	6.6	0.7	0.0	3.7	82	68	67	80	18.0	18.5	18.2	18.4
November	0.0	0.7	4.3	1.0	0.0	4.8	80	68	69	79	14.7	15.1	14.9	14.7
Devember	0.0	1.8	3.3	0.1	0.2	8.0	82	74	74	80	12.4	13.1	12.7	12.4
Year	0.1	8.5	27.0	10.6	0.5	60.1	82	66	65	80				

Period of Observations July 1957 - June 1967

Period of Observations 1961 - 1966

Wind Strength - Percentage Frequencies of Mean Speed At
03, 09, 15, 21 GMT *July 1957 - June 1962*

	Calm	01-03 KT	04-06 KT	07-10 KT	11-16 KT	17-21 KT	22-27 KT	28-33 KT	Highest Gust (KFT) 1947-1966
December January February	7.5	8.8	14.5	26.0	25.4	11.3	5.8	0.7	59 61 70
March April May	9.7	12.8	15.2	23.2	22.0	11.8	4.8	0.5	60 55 53
June July August	21.7	17.2	18.0	24.4	13.5	4.1	1.1	0.0	47 43
September October November	13.7	12.8	16.6	26.6	20.3	7.1	2.5	0.3	50 54 58

Wind Direction - Percentage Frequencies of Various Directions
and Mean Speed 4 KT, or More July 1957 - June 1962

	350/ 010^o	020/ 040^o	050/ 070^o	080/ 100^o	110/ 130^o	140/ 160^o	170/ 190^o	200/ 220^o	230/ 250^o	260/ 280^o	290/ 310^o	320/ 340^o
December January February	3.9	2.5	4.0	3.8	3.4	3.6	5.9	7.9	8.4	12.7	17.5	10.1
March April May	2.7	3.4	4.5	6.1	5.2	5.9	4.6	5.4	4.6	7.9	17.0	10.2
June July August	3.2	2.9	3.6	2.5	3.9	3.7	3.5	5.3	3.4	4.4	13.4	11.3
September October November	2.5	2.3	4.4	6.6	7.5	7.6	7.6	7.1	4.2	5.7	10.7	7.3

2.4 Tidal Current, Tide and Wave

1) Tidal current and Tide

The tidal current in the Mediterranean Sea is as shown in Fig. 4. The local tidal currents through the channels have not been clarified due to lack of detailed records but the speed of current is supposed not to exceed 1 knot.

The tide rises and falls slightly but irregularly and the values obtained at Valletta are shown in Table 3.

Table 3 Tide

Place	Height above datum of soundings			
	High Water		Low Water	
	Mean Springs	Mean Neaps	Mean Springs	Mean Neaps
Valletta	1.3 feet (0.39 m)	1.1 feet (0.33 m)	0.7 feet (0.21 m)	0.9 feet (0.27 m)

2) Wave

No result of wave observation was obtained but it is presumed that the sea may run in some 4 meters high.

2.5 Earthquake

Mary Abela reported that the earthquake occurred thirty-odd times in the Maltese Islands since 1537. According to "Geology of the Maltese Islands" by Herbert P. T. Hyck, some cases of earthquake involving any damage were reported but no case involving human death reported. Any record was not available for the extent of damage due to and the intensity of earthquakes. In the Maltese Islands the effect of earthquake is negligible and is not taken into consideration in designing structures any noticeable earthquake has not occurred in the Maltese Islands since 1923.

2.6 Clearance of Bridge

The requirements made by Mr. J. G. Gaba, Director of Port & Harbor Bureau, Ministry of Development, to provide clearance for the vessels sailing the Comino Channel are as follows:

1) The only ships which sail the Channel are the ferryboats plying between the islands and yachts.

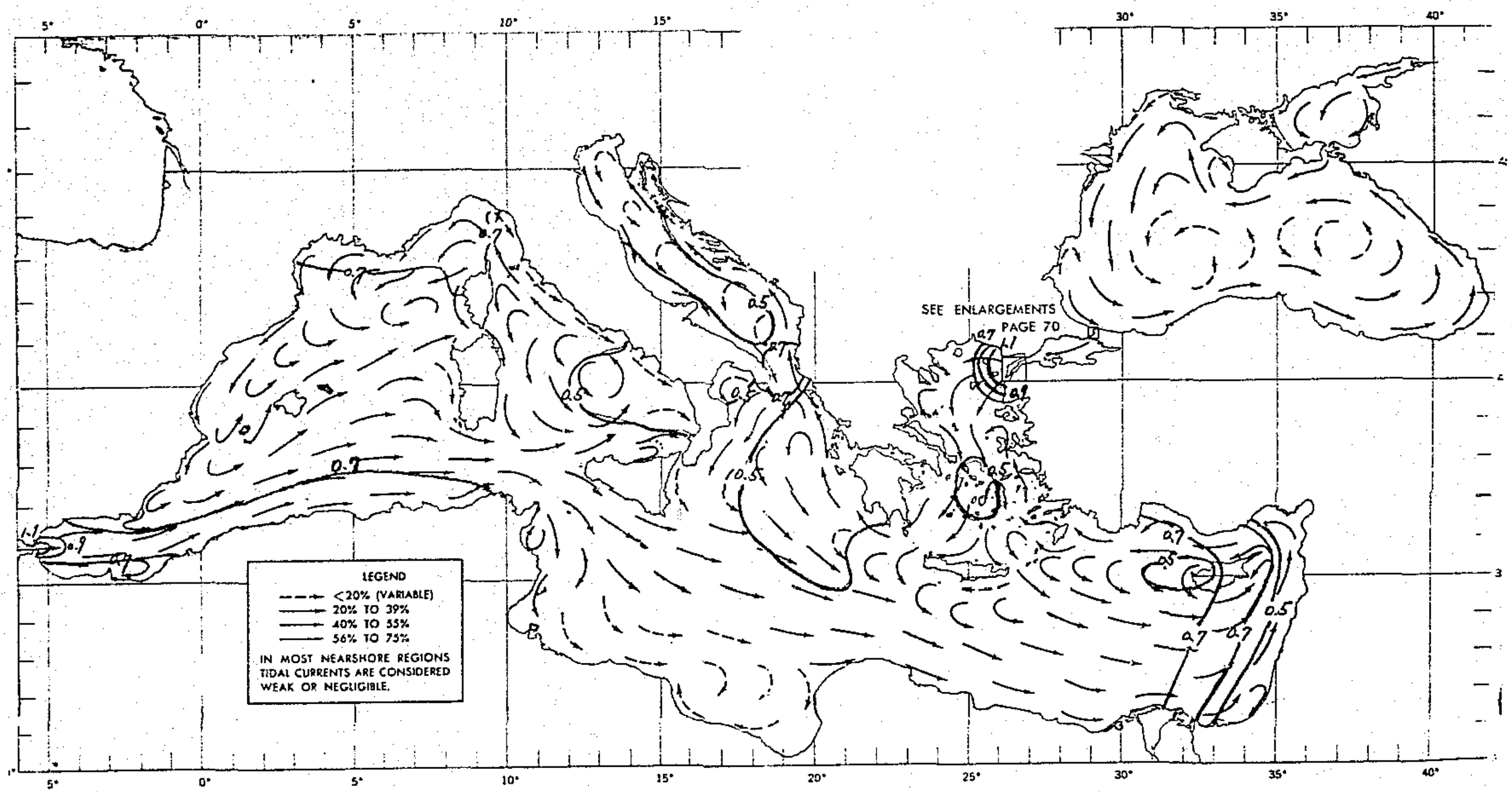


Fig. — 4 PREVAILING SURFACE CURRENTS, MEDITERRANEAN SEA (JANUARY THROUGH DECEMBER)

2) The greatest vessels sailing the Channel are the following ferryboats.

The Jyland - 90 feet (27.4 m) in height and 42 feet (12.8 m) in width

The Calypso - 60 feet (18.3 m) in height and 34 feet (10.4 m) in width

These will require a clearance of 115 feet (35.1 m) in height and 500 feet (152.4 m) in width.

3 Road Plan

3.1 Outline of Proposed Route

Based on a rough field survey the route shown in Fig. 1 was selected for the link road between Malta and Gozo. The principal control points of the route are as follows:

(1) Proposed junction with the arterial highway of Malta (vicinity of STA. 0)

(2) South Comino Channel (S. C. C.) waterside of Malta (vicinity of STA. 3)

(3) S. C. C. waterside of Comino (vicinity of STA. 9)

(4) North Comino Channel (N. C. C.) waterside of Comino (vicinity of STA. 20)

(5) N. C. C. waterside of Gozo (vicinity of STA. 23)

(6) Proposed junction with the arterial highway of Gozo (vicinity of of STA. 28)

The total route length is about 8,720 meters of which the section over S. C. C. is about 1,920 meters and that over N. C. C. about 820 meters.

The design traffic volume has been presumed to be 4,000 vehicles per day for the road planning purpose, though it was impossible to make an accurate estimates in the existing circumstances.

The structural standards of planned road under the design speed of 60 km/hr are as follows:

Design speed	60 km/hr (40 km/hr in special case)
Radius of curvature	120 m (50 m in special case)
Longitudinal slope	5% (+ 3%)

The road is provided with 2 lanes (2 x 3. 25 m = 6. 50 m) and its total width is 8 meters including shoulders (2 x 0. 75 m = 1. 50 m). The standard cross-section shown in Fig. 5 is applied in common to road, bridge, tunnel and causeway. The road section over the channel is required to be constructed so as to provide vessels with a route of about 35 meters high above the sea level and about 150 meters wide. If a tunnel is constructed to cross the channel, such route over it must have a navigable water depth of 10 meters below the sea level. In any case the said route is provided in S. C. C. only. The surface of road is maintained at least 5 meters or more above the sea to prevent any effect of wave. These requirements have not a little effect on the planning of the route section crossing the bhannel.

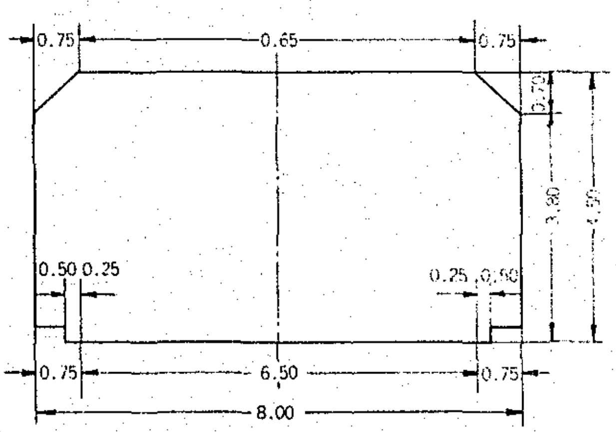
In locating route sections on the land any particular obstacle was found from the results of the reconnaissance; the geological features are generally so good that the grade and longitudinal alignment may be secured in conformity with the structural standards and that the road can be planned by connecting the existing arterial highways of Malta and Gozo by a route of the shortest distance. The geology of the channel is of uniform rigidity and it was judged to be most economical to cross it through the most shallow route because the cost of construction seems to depend largely on the depth of water.

Based on such way of thinking the planned grade and profile were prepared with the data obtained from the survey in advance, which are shown in Fig. 6 and 7.

The design standards of structures (load, structural details, standards applicable to materials to be used) to be constructed on the route are as specified in the relevant Japanese specifications.

Fig.-5 Standard Cross-sectional View (Construction Gauge)

unit in m



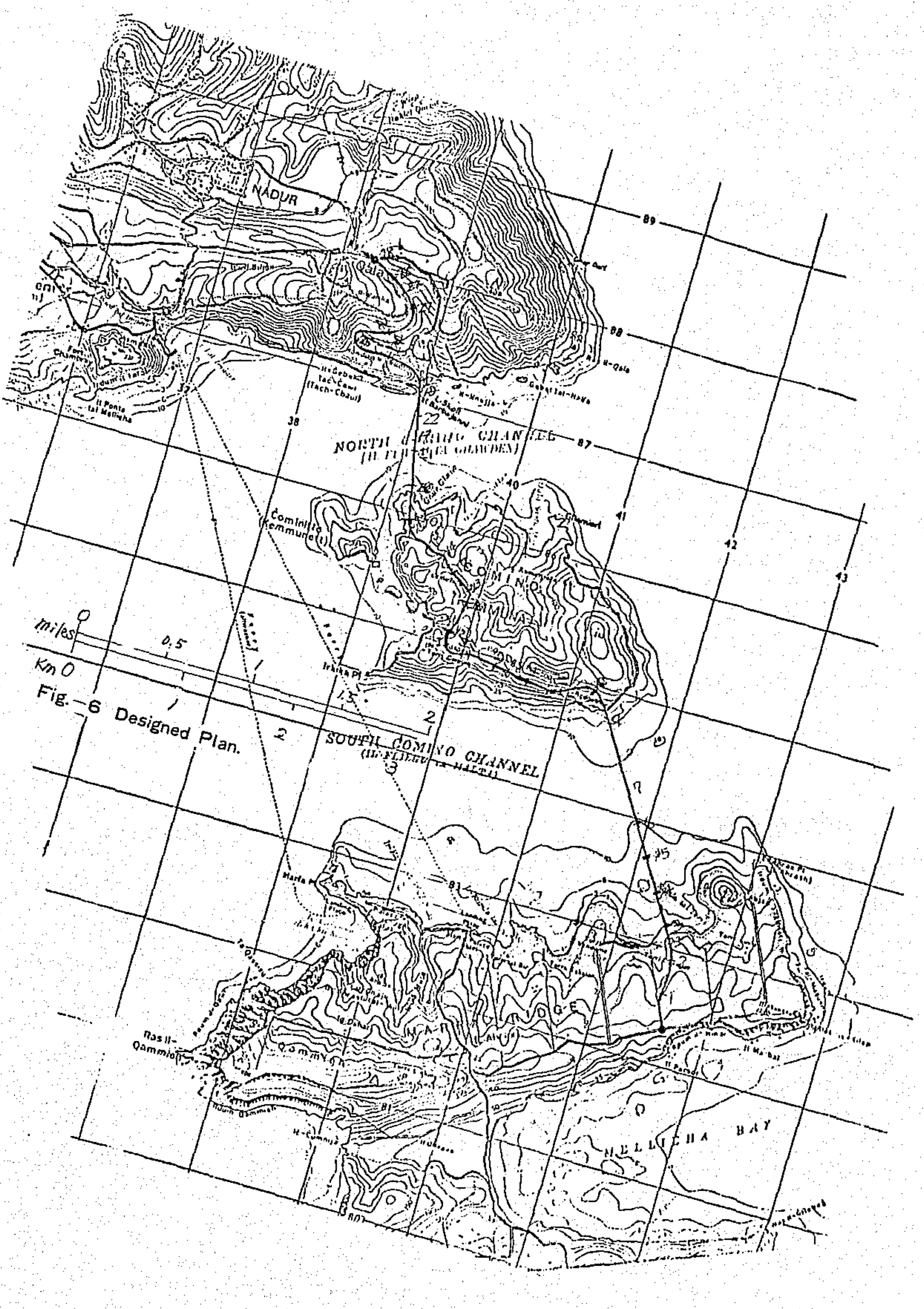
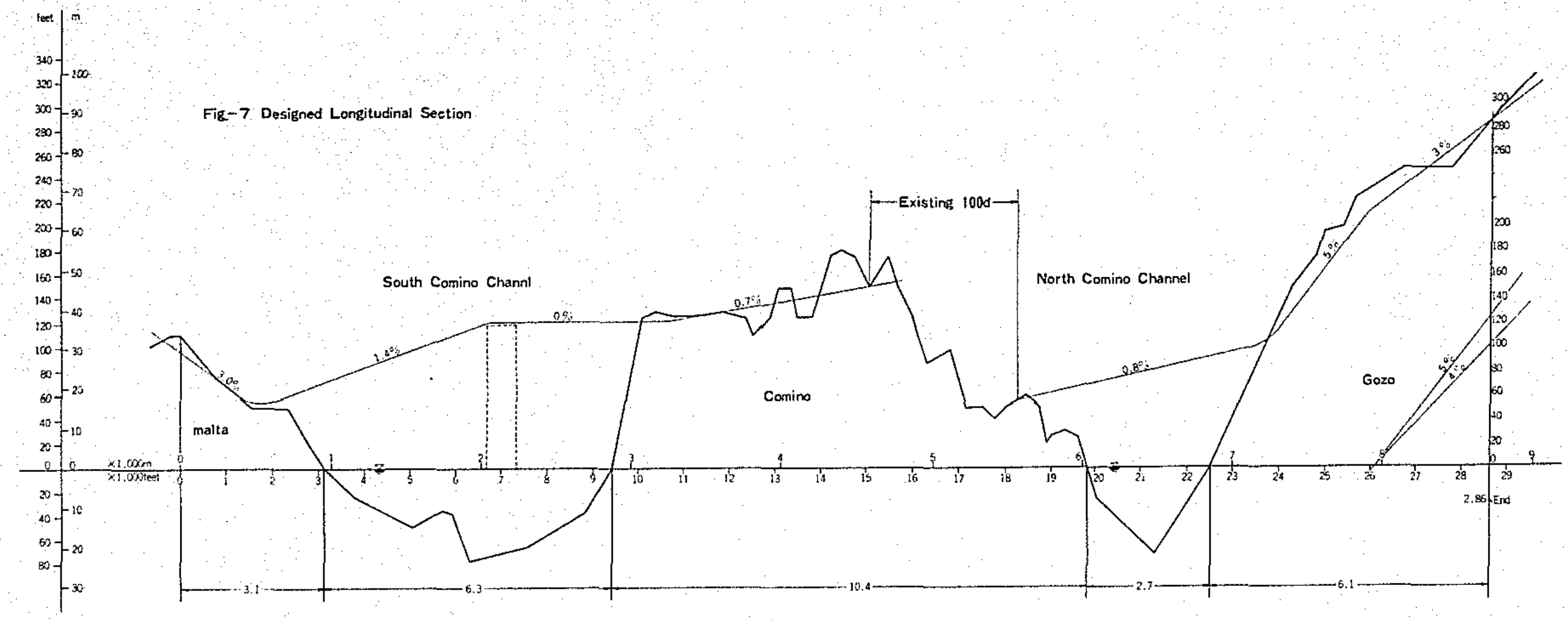


Fig.-6 Designed Plan.

Fig.-7 Designed Longitudinal Section

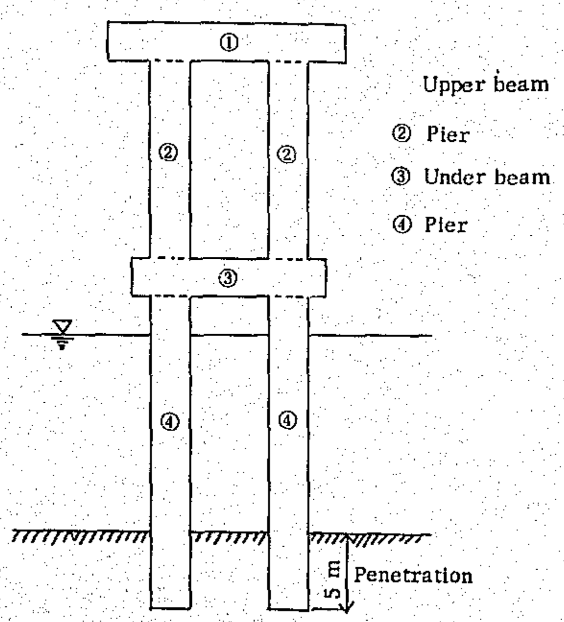


3.2 Bridge

The plan for crossing the channel by a bridge is described below.

The limestone group composing the subgrade of the bridging site seems to have a satisfactory bearing capacity to support the foundation of bridge. It has been presumed that any soft deposits do not occur on the seabed of the channel. Needless to say, a geological survey by mean s of boring, etc., will be required in future to draw a clear conclusion. Also, without a sufficient survey having been made, only a loose presumption on the topography is possible based on the hydrographic chart. Seismic load has not been taken into account.

The construction of substructures in the sea as deep as 25 meters at the maximum involves various difficult problems as differed from works executed on the land and, therefore, the basic type of foundation should be determined based on the thorough examination of working conditions. The construction method to be used is as follows. A working platform is established to operate a rotary drilling machine, with which holes are excavated by means of circular drilling. The diameter of a hole is 2 meters for the foundation of the center span and 1.5 meters for that of the side span. Precast prestressed concrete piles (2.0 or 1.5 meters in diameter) are embeded in the holes and the fill is placed by underwater concreting to form the piers (Fig. 8). It was judged to be most advantageous to construct the lower girders, pier, and upper girders by placing concrete in the open air. The construction of piers is performed entirely in the sea. In carrying out other works, all labor, materials and equipment must be transported to the site by ship and the operations are apt to be affected by the climatic conditions, thus necessitating longer construction period. A work yard will be necessary in order to minimize the operations on the sea and work ships will need a wharf.



(1) Upper girder
(2) Column
(3) Lower girder
(4) Pier

Fig. 8 Pier General Section

As for the superstructure, the normal practice of bridge designing is that the superstructure works over the channel are provided with longer effective spans so as to reduce the number of substructure works. In addition, in the present plan, it is necessary to provide an effective span of about 150 meters or more for the center span in order to secure the clearance for navigation.

Taking these factors into consideration, the designing and trial calculation of cost were made for the following two cases.

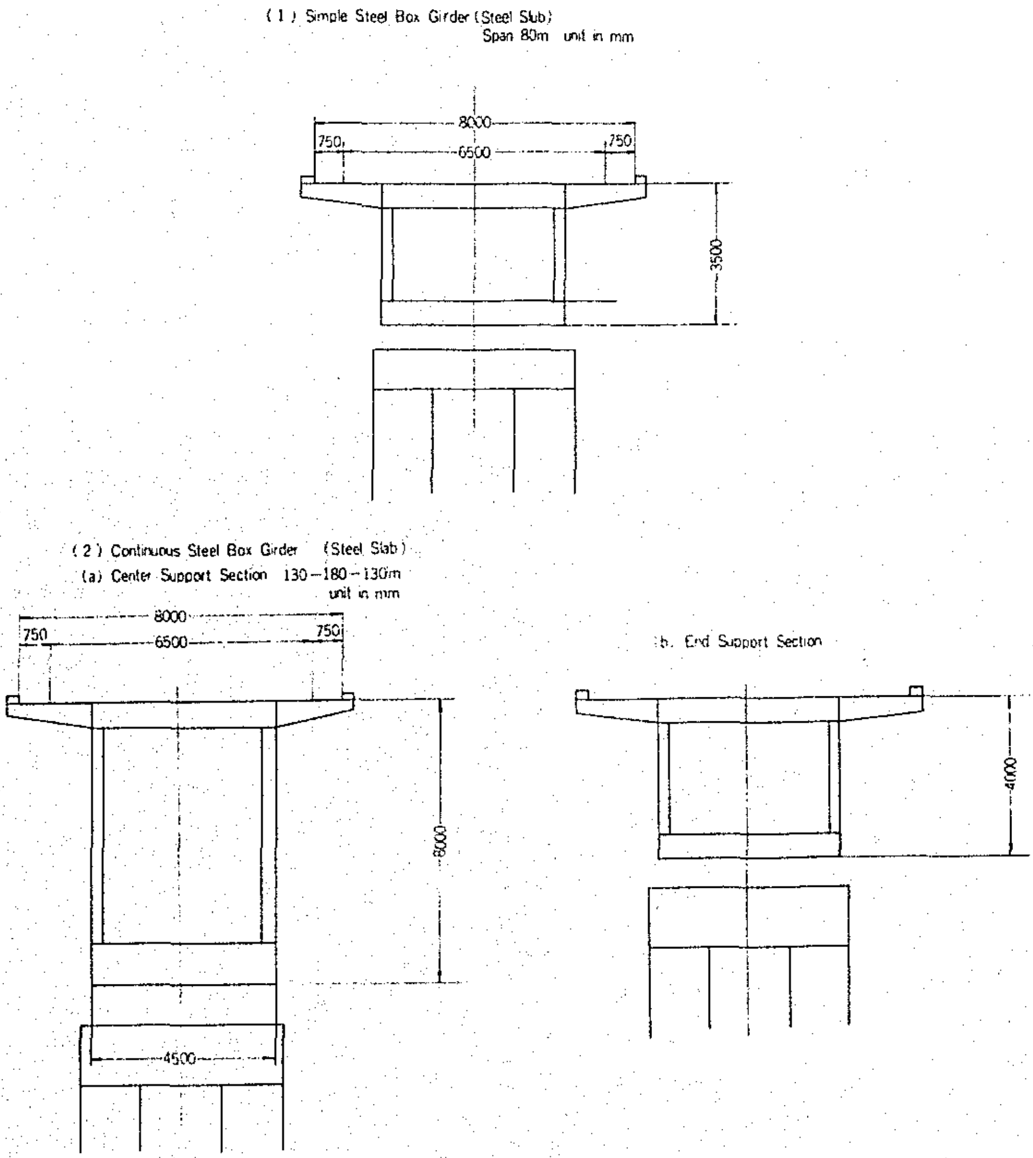
Case 1 (Fig. 9)

S. C. C.

Center span: Continuous steel box girder (steel floor slab)

Effective spans of 130 - 180 - 130 m

Fig.-9 Bridge (case 1)



Side span: Simple steel box girder (steel floor slab)
Effective span of 80 m, 17 spans

N. C. C.
Simple steel box girder (steel floor slab)
Effective span of 80 m, 14 spans

Case 2 (Fig. 10)

S. C. C.

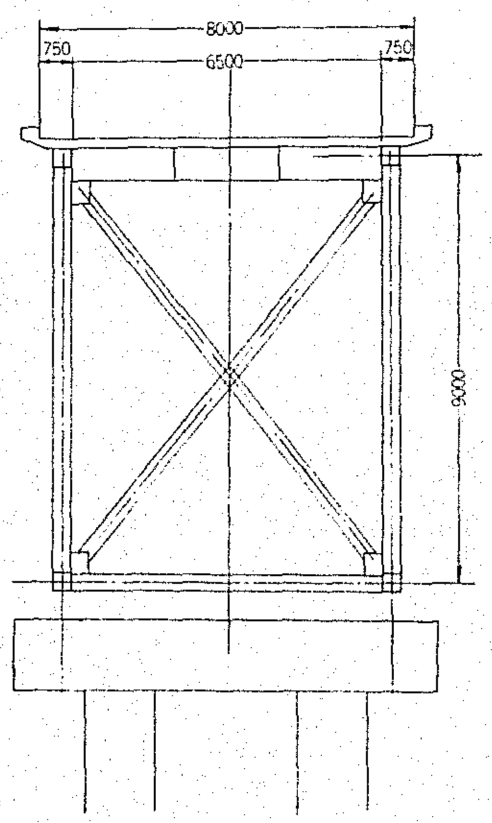
Center span: Continuous truss (concrete floor slab)
Effective spans of 115 - 180 - 115 m

Side span: Simple truss (concrete floor slab)
Effective span of 100 m, 13 spans

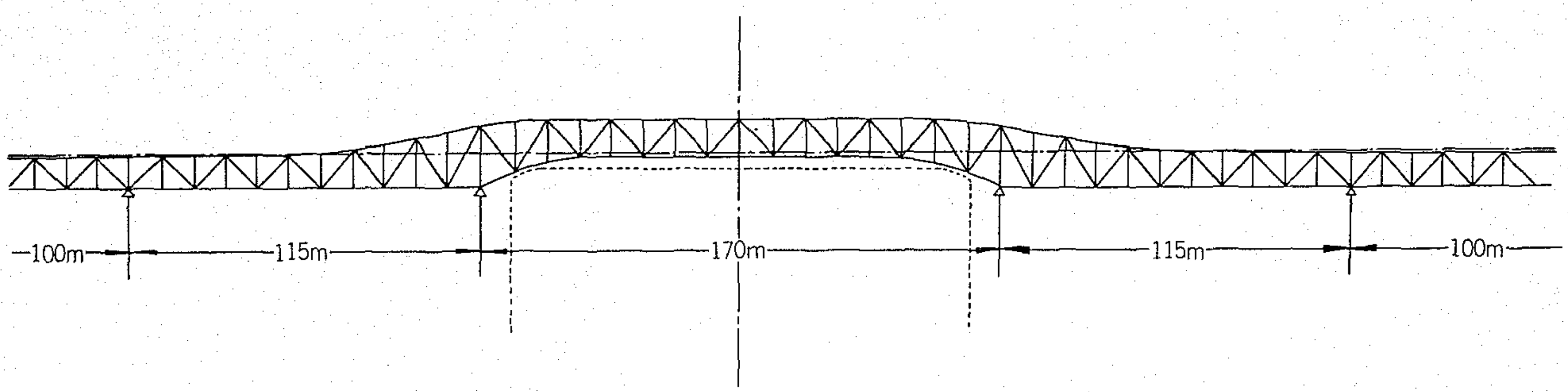
N. C. C.
Simple truss (concrete floor slab)
Effective span of 100 m, 10 spans

Fig.– 10 Bridge (case 2)

(1) Simple Truss (Concrete Slab) Span 100m unit in mm



(2) Continuous Truss (Concrete Slab)   Span 115m－170m－115m



The estimates of the quantity of materials and the cost of construction for the above 2 cases are as follows.

Materials

Case 1

Length (m)	Superstructure works	Substructure works	
	Steel materials (t)	Concrete (m^3)	Steel materials (t)
S. C. C. 1, 787	7, 000	4, 200	420
N. C. C. 1, 120	3, 800	1, 800	180
Total	10, 800	6, 000	600

Case 2

Length (m)	Superstructure works		Substructure works	
	Steel materials (t)	Concrete (m)	Concrete (m)	Steel materials (t)
S. C. C. 1, 700	6, 500	2, 700	4, 100	410
N. C. C. 1, 000	3, 400	1, 600	1, 400	140
Total	9, 900	4, 300	5, 500	550

Cost of Construction (hundred million yen)

Case 1

	Superstructure works	Substructure works	Total
S. C. C.	26. 0	8. 8	34. 8
N. C. C.	13. 4	4. 0	17. 4

(US$17 million)

Case 2

	Superstructure works	Substructure works	Total
S. C. C.	22. 6	8. 3	30. 9
N. C. C.	11. 2	3. 4	14. 6

(US$14. 8 million)

The cost of construction for S. C. C. in Case 2 is somewhat less than that in Case 1. However, in Case 2 for N. C. C., the truss height which is about 9 meters is excessive to provide such siffucient room beneath the truss as is deemed desirable.

When the concrete bridge is to be constructed instead of the steel bridge, the long span system cause greater weight of structures as a whole even if prestressed concrete strucutres are applied; this necessitates to accomplish more rigid substructure works and the erecting is not easy. Moreover, a very difficult administration of works is required to complete the structures of good quality. In view of these facts it was found for the present plan that the concrete bridge is not preferable even though the cost of construction is less than that for steel bridge.

3. 3 Prefabricated Subaqueous Tunnel (Submerged Tunnel)

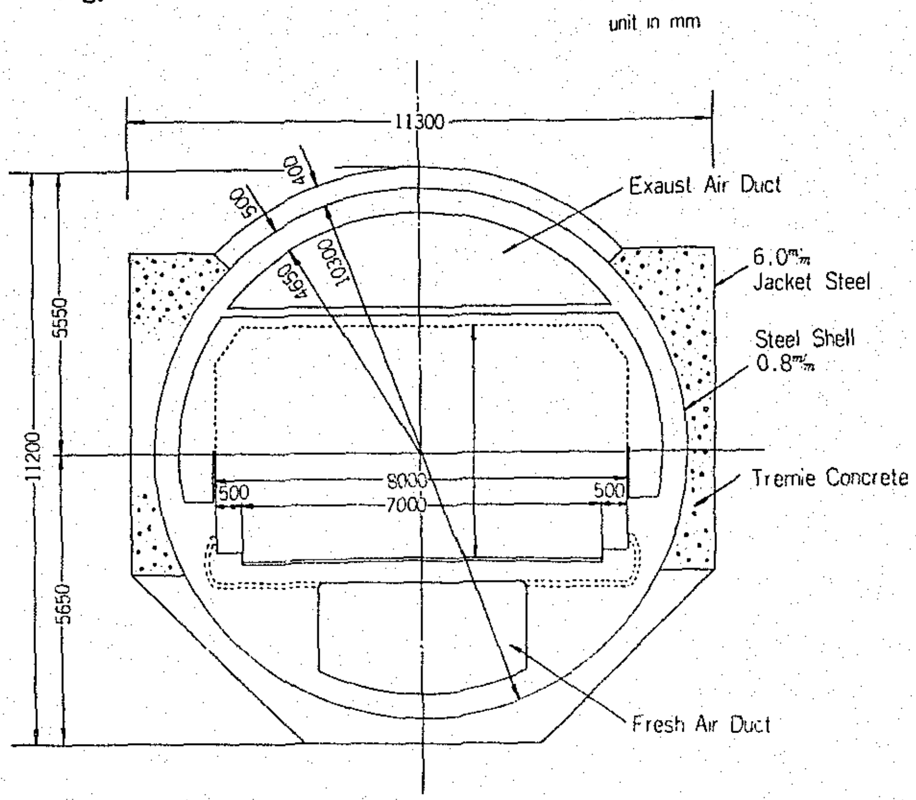
Submerged tunnel may be an applicable type of structure judging from the topography clarified by the rough field survey and the data such as hydrographic chart. The planning of submerged tunnel requires various survey data about the channel. However, such data being almost unavailable, the plan was prepared on the assumption that the geology and tidal current of the channel constitute the conditions favorable to the construction of such tunnel. However, the submerged tunnel will not be planned for the North Comino Channel, because a satisfactory profile to meet the structural standards cannot be secured by reason of the construction cost.

Several examples of submerged tunnel with two lanes are found in the world and the sectional form shown in Fig. 11 is an almost completed pattern at the present day. In this form, a provision is made for transverse ventilation to deal with the traffic volume exceeding 5,000 vehicles per day but jet funs will be sufficient until such traffic volume is reached. The costs for installing and maintaining such ventilating device are almost negligible.

The adequate depth of water is 10 meters to secure a satisfactory sea-route through S. C. C.

Taking the longitudinal slope of road surface into consideration, the route width of 150 meters can be secured with the water depth of 10 meters. So far as the location where the sunken tube is placed meets such requirements, the cost of construction will be reduced in proportion to the depth of water decreased. However, a thorough examination is necessary for the settling of sunken tube and insuring its

Fig.-11 General Cross Section of Sunken Tube



stability in the lateral direction.

Taking the working condition in S. C. C. into consideration, three methods may be conceivable for constructing the submerged tunnel in the channel. Plan 1. When it is presumed from the topography of the site that no deposit is on the seabed, the bedrock is excavated to the depth (about 4 meters) of 1/3 high of the sunken tube which is placed in the excavated trench. The longitudinal and cross sections for this construction method are shown in Figs. 12 and 14. This method needs somewhat higher cost of construction but is the most reliable method. Plan 2. As in the Plan 1 the seabed is assumed to be bedrock. In order to minimize the excavation the seabed is levelled by removing protrusions to the minimum extent and the sunken tube is installed on the levelled seabed. In order to obtain the stability of the tube in the lateral direction, rock or debris fills of good quality are required to be placed against the both sides of the tube in sufficient width. The cross section for this method is shown in Fig. 13. Plan 3. The excavation of sea bedrock is applied only to limited parts to reduce the excavation than Plan 2 and embankments are constructed on the sea-bottom for the most part of the base course on which the sunken tube is installed. In this method, a sufficient examination is required for stabilizing the embankments on the sea-bottom, because the settlement of sunken tube exceeding a certain extent becomes fatal to the tube.

Fig.－12 Submerged Tunnel (Cross Section)
－plan 1－

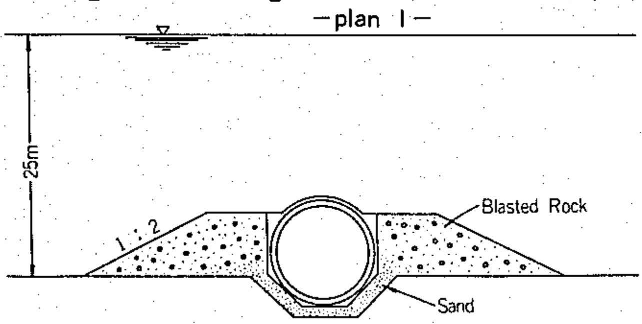


Fig.－13 Submerged Tunnel (Cross Section)
－plan 2－

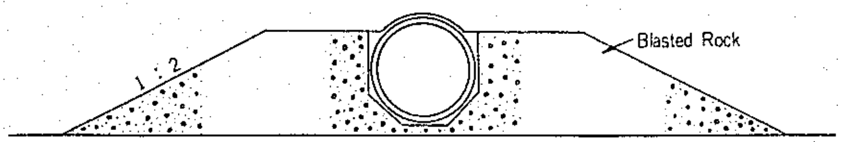
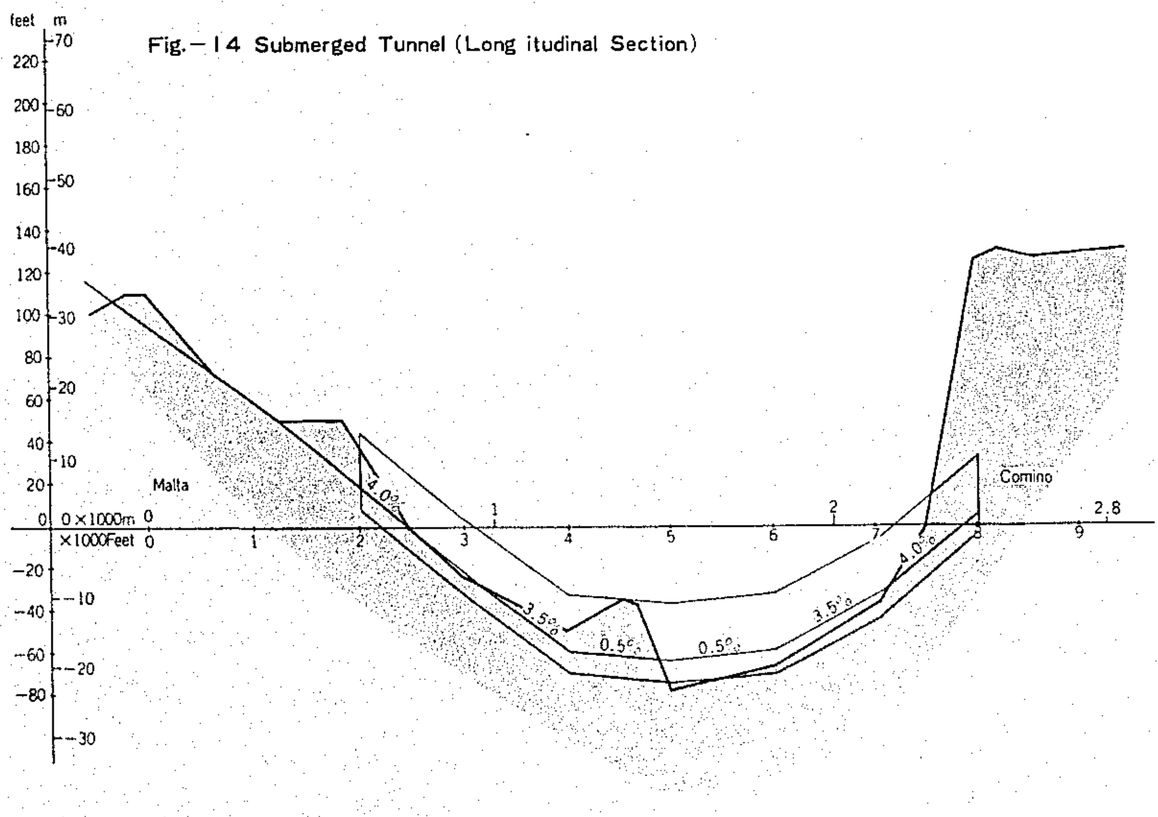


Fig.－14 Submerged Tunnel (Long itudinal Section)



Whichever method is adopted, the element manufactured as a steel shell of 10.3 meters in diameter and 100.0 meters in length at a dockyard is floated on the sea, and towed near to the site of installation. The concrete is placed to form the required section, keeping the steel shell afloat, and then it is sunk and installed on the base course which has been prepared on the seabed by screeding. Rubber gasket is used for the joint, and each element is connected tight by the hydro-static pressure acting on the element and then refilling is carried out.

It is preferable to plan the access road on the side of Comino by means of tunnel and open cut extending about 1 kilometer so as to get through on to the land surface as soon as possible.

The estimates of the amount of materials and the cost of construction when the the submerged tunnel is built by the first method are as follows:

S. C. C. Submerged Tunnel

(about 1,400 meters in length)

Materials:	
Steel materials	5,600 t
Reinforcements	6,000 t
Concrete	75,000 m^3
Cost of construction:	5,400 million yen (US$17.5 million)

The cost of construction for Plan 2 is lower than that for Plan 1 but the examination on the stability of fills depends upon the results of the survey in future. Also the alignment can be improved based on the more detailed survey so that the route can be located which enables to provide more easy access roads to respective islands.

3.4 Causeway

The construction of connecting road is planned by means of levees constructed by mounding rubbles to coffer South and North Comino Channels.

The crown of filled up levee is set at 5 meters above the mean seabed level and water passes are provided at suitable intervals with no navigation taken into consideration. A thorough examination will be required in future for the effect of levees on the environment of the surrounding sea area such as tidal current, wave and sea level as for the riprap material, it has been presumed that rocks of good quality can be produced in various sizes and required quantity from a source near to the site. The subgrade of the channel being a hard bedrock, the riprap works will cause no settlement. The crown of levee over the channel is kept at an uniform height and the access road on each island can be joined to the crown by a slope of 6% in average. In this connection, the access portion will differ somewhat from the planned grade and profile shown in Figs. 6 and 7.

The important conditions in designing the levee are the direction and speed of wind and the wave. The observation records on Malta for 10 years from 1958 to 1967 show that the prevailing gale is northwesterly wind, blowing approximately in the same direction of the center line of levee (Fig. 3). For other wind direction, southeasterly wind is remarkable and it has been presumed that when this wind blows strong, waves of 3-4 meters high act on the levee perpendicular to its center line.

The standard section of reclaimed levee was established as shown in Fig. 15, and in this the following items have been taken into consideration.

(1) The height of crown of levee will be 5 meters above the mean sea level (or 1.5 times of wave height).

(2) Rocks of 5 tons or more will be placed in the layer from 7 meters below the mean sea level 1 or 2 times of wave height) up to the crown of levee to prevent any disturbance by waves.

(3) Rubbles of about 300 kilograms will be placed in the layer lower than 7 meters below the mean tide level.

(4) The inner levee body will be filled with rubbles of about 50 kilograms.

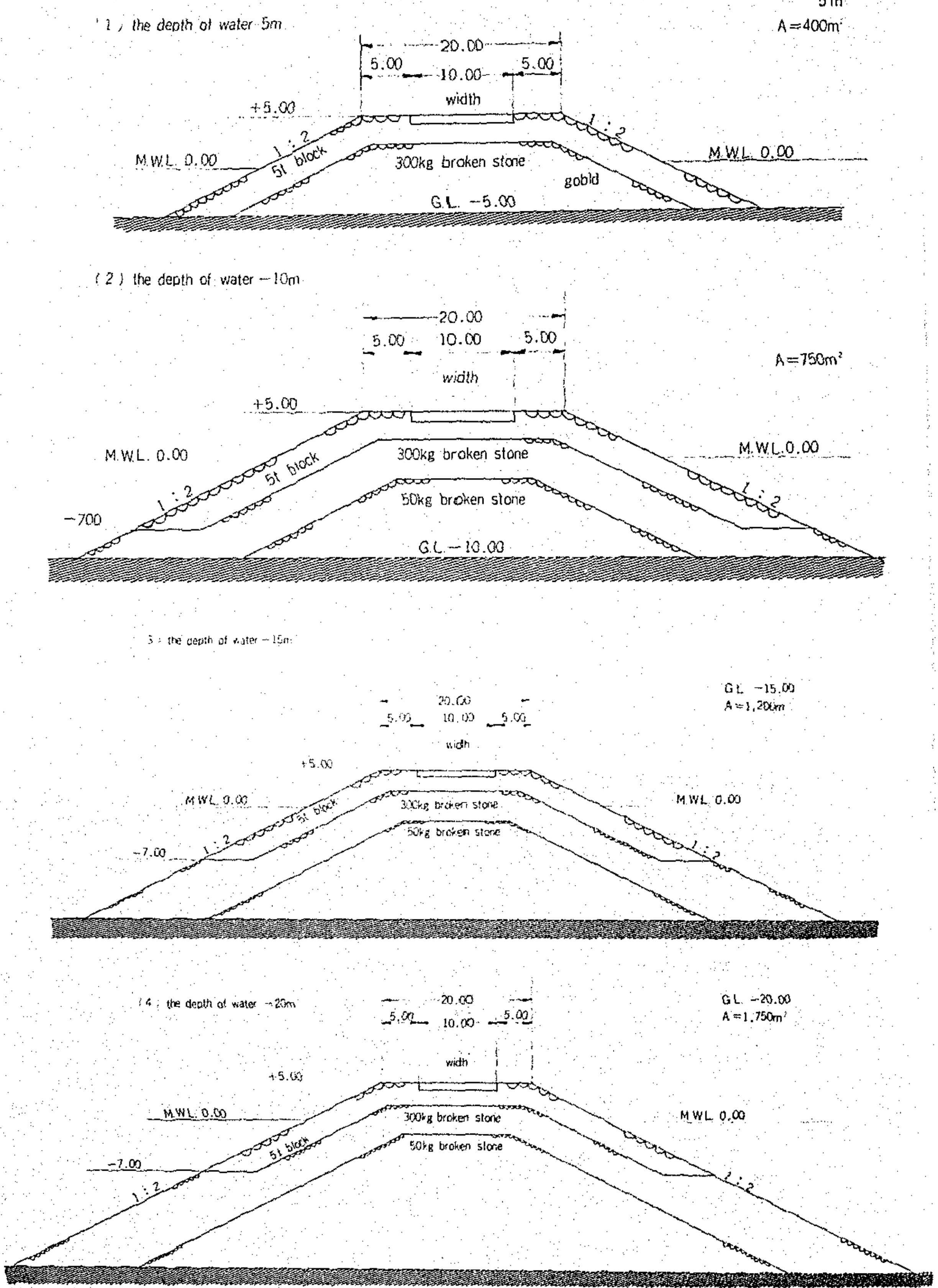
(5) The side-slope of riprap works will be 1 : 2.

(6) The total width of the crown of levee will be 20 meters and at the center of which the road will be planned with a width of 10 meters.

(7) The road surface will have concrete pavement and parapet walls will be provided at the roadsides.

Judging from the topography and geology at the site, the materials for rubble-

Fig.-15 Rubble-mound Breake Water (in m)



mounds will be produced from Comino and Gozo. In excavating the rocks for riprap, all weathered rocks are removed from the surface and rocks of good quality excavated in great mass are crushed as required. Rocks to be used for mounting are carried by road to the wharf and loaded on a bottom-hopper barge. The mounting is started from the water-side and proceeded toward the center of the channel along the center line of levee to be reclaimed.

The volume of riprap materials calculated by applying the standard section of reclaimed levee to the depth of water of the longitudinal section as shown in Fig. 15 is as follows.

Riprap materials

S. C. C.	(1, 570 m in length)	2, 370, 000 m^3
N. C. C.	(713 m in length)	630, 000 m^3
	Total	3, 000, 000 m^3

On the assumption of 1, 800 yen per cubic meter (about US$6/$m^3$) of riprap, the construction cost of levee is estimated as follows.

Cost of Construction

S. C. C.		4, 270 million yen
N. C. C.		1, 130 million yen
	Total	5, 400 million yen (US$17. 5 million)

In this plan, if the navigation route as fixed is to be secured a part of the levee over S. C. C. must be replaced with a bridge or tunnel, which will increase the cost of construction.

3. 5 Comparative Examination of Various Constructural Types

The outline of plans for constructing the link road between Malta and Gozo is described in paragraphs 3. 2, 3. 3 and 3. 4 where the structural types include bridge, tunnel and causeway.

The tunnel has an advantage in securing the required clearance for navigation route, but is planned only for S. C. C. because of a difficulty in planning for N. C. C. Among the three types, the highest cost of construction is estimated for the tunnel, of which construction works themselves are more difficult than those of other two types and, in addition, the joint use system of the tunnel will increase the maintenance expenses.

The construction cost of the reclaimed levee is lower than that of the tunnel but higher than that of the bridge. However, in the plan prepared herein the longitudinal section of the channel portion is fixed uniformly at 5 meters above the mean tide level and any navigation route is not secured. It is clear that if such route is to be taken into consideration the cost will increase. The plan is prepared on the assumption that the ripraps to be used for constructing levee will be produced in the required quantity of good quality and various sizes from the vicinity of the work site. Therefore, if these materials must be obtained from a remote source and transported to the site the construction cost will run up substantially. The change in the environment should be thoroughly examined in the area around the channel.

Eventually, the bridge is most economical in terms of the cost of construction. However, in the present plan of the bridge over S. C. C. the spans are simply divided into center and side spans in order to secure the navigation route, and the superstructure works to be mounted approximate to the greatest one which has been ever designed for a bridge to cross a channel. The manufacture and erection at site of such a large scale bridge are supposed not to be so easy and there seems to be a scope for studying minutely the optimum type of bridge also taking into consideration the economy and aesthetics.

The undersea construction of substructure works also involves many difficult problems.

The planned route extends for about 8, 720 meters originating at the arterial highway (STA. 0) of Malta Island to terminate at the arterial highway (STA 28. 6) of Gozo through Comino. The total cost of construction is estimated at about 5, 500 million yen (US$17. 9 million) including 4, 800 million yen (US$15. 6 million) for the channel section and 700 million yen (US$2. 3 million) for the road section on the land. The unit prices used for estimating the cost are the average prices in Japan as of March, 1972. The above cost of construction may well vary when the minute investigations will have been made in the designing and working conditions relating to the construction of this link road.

4. Forecast of Traffic Volume

4.1 Economic Indicators

The various economic indicators of the State of Malta for 1964, 1965 and 1970 are shown in Table.4.

Table 4 Economic Indicators

Item	1964	1969	1970
Area (Sq. miles)	122	122	122
Population (thousand)	323	322	325
Population density (No. per sq. miles)	2, 654	2, 642	2, 666
Gross National Product at Market Prices (£ M)	53. 3	88. 3	-
Total personal income (£M)	48. 2	179. 2	-
Total personal income per person (£)	159	246	-
Exports f.o.b. (£ M)	6. 9	16. 0	15. 9
Imports c.i.f. (£ M)	34. 6	61. 5	67. 5
Number of cars (number)	31, 202	51, 192	56, 369
Private cars owned (number)	19, 402	35, 158	39, 514
Cars for hire (number)	1, 092	2, 031	2, 250
Buses (number)	616	623	621
Commercial vehicles (number)	6, 251	9, 845	10, 714
Motor cycles (number)	3, 841	3, 535	3, 270
Number of cars per thousand persons (number)	97	159	173
Mileage of public roads (miles) (total)	687	760	-
Paved or asphalted (miles)	543	647	-
Total tourist arrivals (number)	37, 573	186, 084	170, 853
Hotels (number)	36	101	110
Hotel beds (number)	2, 360	7, 562	7, 935

4.2 Estimation of Traffic Volume

In planning road, the macroscopic estimation of future traffic volume is usually made in the following way. The future growth in population, gross national product and national income is forecasted to estimate the growth in the car ownership, and the future traffic volume is estimated based on the growth in car ownership as well as the present traffic volume. However, because of the special circumstances of Malta such as that the density of population is very high, that the number of cars owned as of 1971 has already reached the level of European countries as of about 1967, and that the balance of trade is more dependent upon the income from the invisible trade such as tourist industry rather than the export promotion and the prospect of tourist industry is highly evaluated in the future master plan, the estimation of traffic volume for the link road has been made on the basis of the growth of tourist industry, that is, in relation to the number of tourists visiting this country, as well as taking into consideration the value of Gozo Island as a tourist resort.

Table 5 and Fig. 16 show the number of cars owned and arriving tourists and the volume of car traffic by the ferryboats operating between Malta and Gozo in recent Malta. The volume of traffic has increased rapidly in recent years independently of the growth in the number of cars owned and this increase approximates to the grows in the number of arriving tourists, though it is not soclear due to the lack of intermediate figures for 1967 and 1968. In spite of the fact that the tourist traffic in the country is expected to grow from the opening of the link road, the estimation of traffic volume by this method will not be necessarily underestimate in view of the retention in the growth in the number of arriving tourist for 1970. The point is the number of arriving tourists in future; the Master Plan of Malta anticipates that the hotels will accommodate 13, 500 beds by 1973 and the number of arriving tourists will be 500 - 600 thousand persons per year by early 1980's. These targets may be considered to have a substantial possibility since the number of beds has reached to 8, 000 in 1970. The traffic volume on the link road estimated based on the above figures is shown in Fig. 17.

Table 5 Number of cars, Traffic volume between Malta and Gozo, and Total tourist arrivals

Year	Number of cars	Traffic volume	Total tourist arrival
1960		12,344	19,689
1961		13,317	22,611
1962		10,557	23,334
1963		12,985	32,299
1964	31,202	12,479	38,380
1965		14,053	47,804
1966		14,879	72,889
1967	40,209	19,221	
1968	45,110	35,522	
1969	51,895	59,111	186,084
1970	57,147		170,853

Fig.-16 The Numbers of Cars Tourists and Traffic Volume A Year Between Malta and Gozo

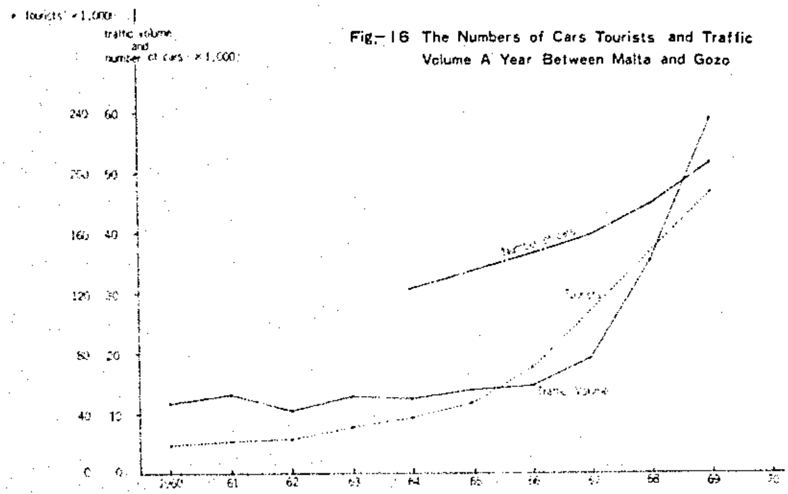
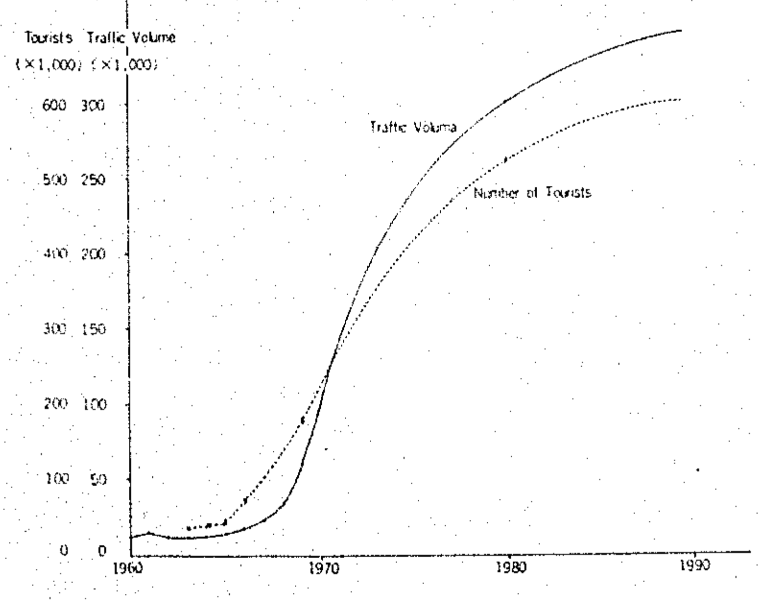


Fig.-17 Estimated Traffic Volume



In terms of traffic capacity, the greatest traffic volume occurs in August as the tourist season is summer and it accounts for 15 - 20% of the annual traffic volume. If the traffic volume for 1980 is estimated at 300 thousand cars, the maximum monthly traffic will be about 60,000 cars and the daily traffic about 2,000 cars with 4,000 cars being for holiday at two times of that of weekday; thus the link road planned with two lanes will be sufficient to handle the estimated traffic volume.

5. Payability as Toll Road

The charges of the ferryboats operating at present are as follows:

Car:	8 - 12.5 shillings (320 - 500 yen)
Motorcycle	3 shillings (120 yen)
Passenger	2 shillings (80 yen)
Round trip	3 shillings (120 yen)

Because the growth in motorcycle traffic in weakening and the passenger traffic will be transferred to bus, these have been omitted. If the charge levied on a car is 10 shillings (400 yen) in average, the annual revenue for 1980 will be about 120 million yen (US$316 thousand), from which expenses such as maintenance and operating costs must be put aside. Therefore, it will be impossible to redeem the construction cost of 5.500 million yen (US$17.8 million) if the interest bearing fund is used.

6. Postscript

The designing and working conditions must be defined prior to the implementation of the construction works of the link road, and this requires to carry out the survey of the following items.

(1) Survey on the topography and geology of the seabed
(2) Survey on wind (wind direction, wind speed, and fetch)
(3) Survey on wave (wave height, wave direction, and wave force)
(4) Survey on tidal current (current speed, current direction, and tidal range)
(5) Survey on construction equipment, materials, and worker
(6) Survey on the structural standards of road and the navigation route through the channel

These surveys will require several years to complete, and are desired to be accomplished promptly so that the link road can be constructed losing no time.