社会開発調査部報告書

JAPAN INTERNATIONAL COOPERATION AGENCY

No. 2

MINISTRY OF AGRICULTURE, WATER MANAGEMENT AND FORESTRY
BOSNIA AND HERZEGOVINA

THE FEASIBILITY STUDY ON THE WASTEWATER TREATMENT PLANT OF SARAJEVO CITY IN BOSNIA AND HERZEGOVINA

FINAL REPORT

VOLUME Ⅲ : ASSESSMENT WORK REPORT

NOVEMBER 1999

TOKYO ENGINEERING CONSULTANTS CO., LTD.
NIHON SUIDO CONSULTANTS CO., LTD.

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CONSTITUENT VOLUMES

VOLUME I	SUMMARY REPORT
VOLUME II	MAIN REPORT
VOLUME III	ASSESSMENT WORK REPORT
VOLUME IV	APPENDIX

EXCHANGE RATE

KM 1.00 = DEM 1.00 = JPY 71.20

(Status as of 24 May 1999)

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VOLUME
III

ASSESSMENT WORK REPORT

CHAPTER 1. OUTLINE OF THE WORK

The field survey and assessment work for the existing Sarajevo WWTP was carried out on 25th May to 3rd August 1999. The main purposes of the work include the following:

(1) to get the present status of the existing facilities and auxiliaries
(2) to determine the extent of damage in order to propose for the most viable action for remedial works/replacement
(3) to collect data & information on serious operational and maintenance problems necessary for the improvement of the facilities and treatment process
(4) to check the plant capacity and treatment process for long term planning, and
(5) to formulate the most viable alternative for its rehabilitation

Several works and tests were conducted during the above-mentioned period such as the following:

(1) initial appraisal of the facilities
(2) collection of available drawings and checking them against the as-built condition
(3) on site tests
(4) sample collection for laboratory analysis
(5) visual condition survey including photo-documentation
(6) data gathering on related information such as material, labour and costs
(7) environment and sludge disposal
(8) data interpretation and analysis, and
(9) evaluation for the proposed action.

1.1 WORKS CARRIED OUT BY THE STUDY TEAM

The Study Team carried out several works and investigations on the existing treatment facilities that include the structural buildings and treatment facilities, mechanical and electrical equipment & auxiliaries. The Study Team also studied/analysed the most viable treatment process that will make the Sarajevo WWTP a less troublesome and environmentally friendly WWTP once it goes back into operation. These works as will be discussed in the later sections were carried out separately for every aspect such as civil, architectural, mechanical and electrical. The corresponding data sheets/survey reports and tests for each facility are shown in the **Appendix**.

1.2 TESTS CARRIED OUT BY THE CONTRACTOR

A local contractor, USB Kedly Doo, Sarajevo was tasked to assist the Study Team in some aspects of the field survey and assessment of the treatment facilities. An agreement, which was signed by the Study Team and USB Kedly on 25th May 1999, specified the works carried out by the contractor on a period of 60 days starting 31st May 1999. The contract was concluded with the signing of the Certificate of Final Acceptance on the 19th July 1999. The results of all works/tests carried out by USB Kedly in cooperation with The Institute of Materials and Structures (IMK), Faculty of Civil Engineering, University of Sarajevo is discussed in a separate report as follows:

(a) **Elaborate on Tests Carried Out on Aeration Tank, Aerated Grit Chamber and Underground Pipelines of the Sarajevo WWTP**
Institute for Materials and Structures (IMK), Faculty of Civil Engineering, University of Sarajevo
July 1999

(b) **Final Report on The Field Survey and Assessment of the Sarajevo WWTP**
USB Kedly Doo, Sarajevo
July 1999

In the course of the contract, weekly meetings (Refer to Minutes of Meeting compiled in the **Appendix A**) between the Study Team and the contractor were held to monitor the progress of work and for any important issue/matter to be discussed/resolved. The contractor carried out the activities, works and tests required for the field survey and assessment of the Sarajevo WWTP that include the following:

1.2.1 Aerated Grit Chamber – Concrete Stress Strength Testing, Investigation of Neutrality and Inspection of the Reinforcements

In this particular activity, the contractor conducted visual inspection including photo-documentation and collected from the structure's walls and floor 12 cylindrical concrete core samples and 3 series of 3 reinforcing bar specimens for laboratory analysis. On-site pH tests of the concrete structure were also done. Experts from the Institute for Materials and Structures, Faculty of Civil Engineering, University of Sarajevo carried out these works with the report explained in **Appendix F**.

1.2.2 Aeration Tank – Concrete Stress Strength Testing, Investigation of Neutrality and Inspection of the Reinforcements

Similar to the activities done on the Aerated Grit Chamber, the contractor conducted visual inspection including photo-documentation and collected from the structure's walls and floor 42 cylindrical concrete core samples and 3 series of 3 reinforcing bar specimens for laboratory analysis. On-site pH tests of the concrete structure were also done. Experts from the Institute for Materials and Structures, Faculty of Civil Engineering, University of Sarajevo carried out these works with the report included in **Appendix F**.

1.2.3 Underground Pipelines (Sludge Piping)

The contractor, as per instruction from the JICA Study Team engineers collected samples of the sludge pipelines on 4 locations. The collected samples were investigated for their present characteristics to include the type of material, wall thickness, and degree of corrosion. The samples collected were then analysed by the Institute for Materials and Structures. The results are included in **Appendix F.**

1.2.4 Hydraulic Drain Test

Test for leakage of the following liquid retaining structures was conducted to check their water-tightness. The leakage tests were done on the facilities such as, Aerated Grit Chamber, 2 Primary Sedimentation Tank, Aeration Tank, and 6 Final Sedimentation Tank. Water supply from the River Miljacka was pumped to the facilities using submersible pumps. Two days after the water level has stabilised, the drop in water level was started to be monitored. Meteorological data such as precipitation and evaporation were likewise considered in the calculation of the allowable water loss in liquid retaining structures. The data sheets, which include the calculation of water loss due to leakage and meteorological effects, are shown in **Appendix B**.

1.2.5 Load Testing of Aerators

Before testing, a thorough inspection was conducted jointly by the contractor and the JICA Study Team engineers on the aerators. The aerators were investigated and assessed for their mechanical and electrical soundness and structural stability to qualify for testing. Out of the total of the total 33 existing aerators with motors only 19 qualified for testing. Each of the 19 aerators was tested for 2 hours in the condition, as the water level in the aeration tank is normally full. In the duration of the test for each aerator, data and information such as, vibration, noise, oil temperature, etc were taken. A separate inspection on the insulation resistance for each aerator was also done. The results of all these tests and inspection are compiled in **Appendix C**.

1.2.6 Sluice Gate Inspection

As per request by the JICA Study Team engineers, the contractor conducted the inspection of the sluice gates that are existing in the Inlet Chamber (A1), Screening Station (Facility 2), Aerated Grit Chamber (Facility 3), and the Aeration Tank (Facility 5). Data collected include its technical specification, manufacturer, and the existing condition of the gates. This however was not included in the Scope of Works. The data sheets for the sluice gate inspection are compiled in **Appendix D**.

The results of all the tests conducted by the contractor on the investigated structures and equipment including photo-documentation are compiled in the above-mentioned reports, with data sheets that are included in the **Appendix**. However, the works carried out by the Study Team will be discussed in the succeeding sections of this report.

CHAPTER 2. CIVIL WORKS

2.1 INTRODUCTION

Liquid retaining concrete structures at the wastewater treatment plant (WWTP) did not sustain any serious damage as a result of the war. Nevertheless, the structures show considerable signs of deterioration and distress such as:

- weathering of all exposed surfaces,
- extensive cracking in walls with signs of leakage and previous repairs,
- poor workmanship in joint construction and concrete finishes,
- inadequate cover over reinforcement, and
- Rust stains on the concrete, exposed and corroded reinforcement.

Concrete structures should be inspected regularly to examine the condition of the concrete for cracking, leakage, surface deterioration and settlement. Particular attention should be given to any rust stains that might indicate corrosion of the reinforcement. Defects that are detected during these routine inspections should be corrected as soon as possible to prevent the structure from being damaged or shortening the design life.

Since the structures at the WWTP have been neglected for a long time an assessment of their condition was carried out in order to answer the following questions:

- What is the cause and extent of the deterioration?
- Are the structures adequate for the intended purpose in respect of strength, serviceability and durability?
- What will be the future state of structural deterioration?
- What, if any, remedial works are required now or in the future?

In order to answer these questions a systematic program of inspection and appraisal was followed as shown in **Figure 2.1**

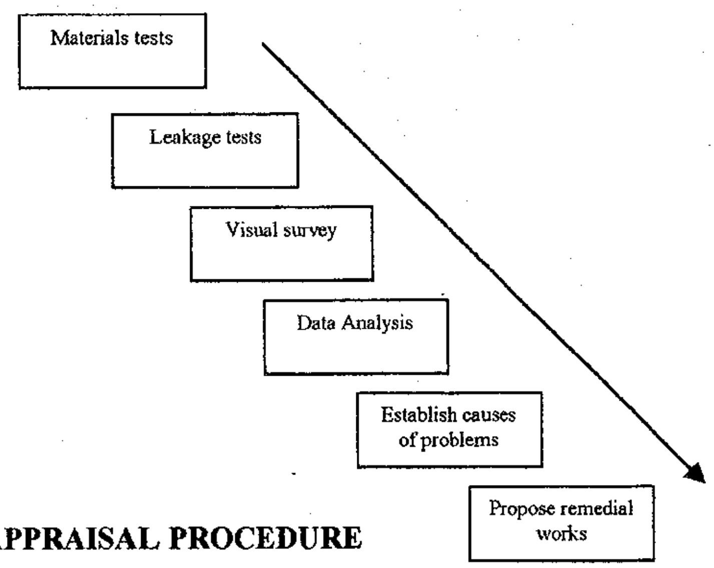


Figure 2.1 INSPECTION AND APPRAISAL PROCEDURE

2.2 MATERIALS TESTING

There are many methods available for testing materials ranging from simple non destructive tests that can be carried out on site to more sophisticated destructive tests that need specialised testing equipment. The following test methods were selected to assess reinforced concrete strength and durability:

- surface hardness test to assess relative strength and quality of concrete
- carbonation depth to assess risk and cause of corrosion
- compressive strength of concrete cores
- tensile strength of reinforcing steel

The tests were selected because they could be carried out locally by the Institute for Materials and Structures (IMK), Faculty of Civil Engineering, University of Sarajevo IMK. The tests also have the advantage of providing reliable results on the strength of materials. The extent and number of test points were selected to provide a reasonable representation of the true state of the concrete.

Hardness tests were conducted by JICA Study Team experts on all structures and results are presented in **Appendix E**

Strength of materials and carbonation (corrosion) tests were conducted by IMK and results are presented in **Appendix F.** Testing for strength of materials was limited to only the aerated grit chamber and the aeration tank because of time constraints.

2.2.1 Carbonation depth

(1) Test Procedure

Carbonation of concrete by attack from atmospheric carbon dioxide results in a reduction in alkalinity of the concrete and increases the risk of reinforcement corrosion. Normally, in good quality concrete, carbonation is restricted to a surface layer of only a few millimetres.

The extent of carbonation can easily be measured by treating with phenolphthalein indicator the freshly exposed surfaces of a piece of concrete that has been broken from a member. A purple red colour is obtained where concrete is good and the highly alkaline content of the concrete is unaffected by carbonation. No coloration will appear in carbonated zones where pH is elevated. The colour change corresponds to a pH of about 9. Reinforcement corrosion may begin at a pH of about 11. The depth of carbonation is recorded to provide an approximate indication of the risk of reinforcement corrosion. Carbonation rates are usually higher in dry or sheltered external concrete than in that exposed to rain or water.

(2) Results & Evaluation

Tests were performed in three locations of the grit chamber and seven locations in the aeration tank.

The depth of carbonation ranges from 10 mm to 20mm as follows:

- 15mm on walls
- 10mm on bottom slabs
- 20 mm on columns of surface aerators

Results indicate a high risk of steel corrosion in many areas where concrete cover is less than 20 mm such as aerator columns and all internal wall surfaces of tanks. The visual condition survey confirms that steel corrosion is extensive. Contributing factors include:

- inadequate concrete cover (less than 20mm)
- porous concrete surfaces

2.2.2 Surface Hardness

(1) Procedure

The quality of concrete was assessed through its hardness by the use of the Schmidt Rebound Hammer. Generally, this is one of the surface hardness methods carried out by impacting the surface of the concrete structure with a specified mass activated by a standard amount of energy. The test is based on the principle that the rebound number of an elastic mass depends on the surface upon which it impinges.

The equipment is operated by pressing the plunger strongly and steadily at right angles against the surface of the concrete structure. The plunger retracts against a spring which automatically releases when fully tensioned, causing the hammer mass to impact against the concrete surface. The rebound of the spring-controlled mass is thus recorded automatically in the attached paper provided in the equipment. The rebound number recorded gives a measure of the relative hardness of the concrete tested.

Except for the floor slab of the screening station, most of the points tested were the vertical wall surfaces and columns of the concrete treatment facilities avoiding form joints, honeycombs and porous areas.

The concrete surfaces were prepared clean and dry by removing any plasterwork or surface coating and making uneven surfaces smooth by hand with the use of the carborundum stone supplied. As much as possible the concrete was grounded off until its normal texture was exposed. The prepared area is approximately 20 cm * 20 cm enough to carry out 12 impact points.

A total of 12 impact tests were carried out on each location. The readings of the test hammer were taken into account, eliminating those obvious "off shots" with further impact tests. Obvious "off shots" are those readings that deviate from the mean of the others by more than 5 units.

(2) Results and Evaluation

The test results are evaluated by calculating the mean or average value as the rebound number, R. The most likely value W_m and Z_m or the cube compressive strength and cylinder compressive strength, respectively are taken correspondingly as a function of the rebound number (Ref. Table II of the Proceq Schmidt Concrete Test Hammer Manual). The results of the concrete strength tests for the treatment facilities are summarised in **Table 2.2.1.** The test location is presented in **Figure 2.2**. The compressive strength as a function of the rebound number is summarised in **Table 2.2.2.** Details of each structure member tested are shown in the Concrete Stress Strength Test Sheet compiled in **Appendix E**

Generally, the concrete structures of the Sarajevo WWTP have the rebound numbers in the range between 39-44. The lower and higher values can be considered as unreliable due to some factors such as carbonation that are prevalent in the Sludge Holding Tank, Sludge Thickener, and Aerated Grit Chamber. Therefore, an average value of R = 41 represents the concrete quality used in the Sarajevo WWTP. Correspondingly, this represents a cube compressive strength and a cylinder compressive strength of 432 kg/cm^2 and 367 kg/cm^2, respectively. These values correspond well to compressive strength obtained by destructive testing of cores samples.

2.2.3 Concrete – Compressive Strength Test

(1) Procedure

Extraction and testing was performed in accordance with Yugoslavian standard JUS U.M1.048 (equivalent to BS 1881 part 120 in the UK and ASTM C42 in the US).

A total of 42 core samples were extracted from the aeration tank and 12 specimens were extracted from the grit chamber. Cores were taken from exterior walls and floor slabs in locations where likely minimum strength coincides with maximum stress. Cores were not taken from aerator columns because members are slender and cutting would likely impair future performance. Core samples 100mm in diameter were mechanically extracted using a rotary cutting tool with diamond crown bit. The core samples were then trimmed to a height of 100mm and the ends capped before visual examination, density determinations and compression testing.

Compression testing was carried out on dry specimens. The mean diameter and height was measured to nearest 1mm by calliper. The pressure was applied gradually until failure by crushing. The maximum compressive pressure on the core specimen was recorded and adjusted to correspond to equivalent cube strength.

Density of each core was determined after compressive testing by removing reinforcement, weighing the concrete and measuring the volume of the trimmed core by water displacement.

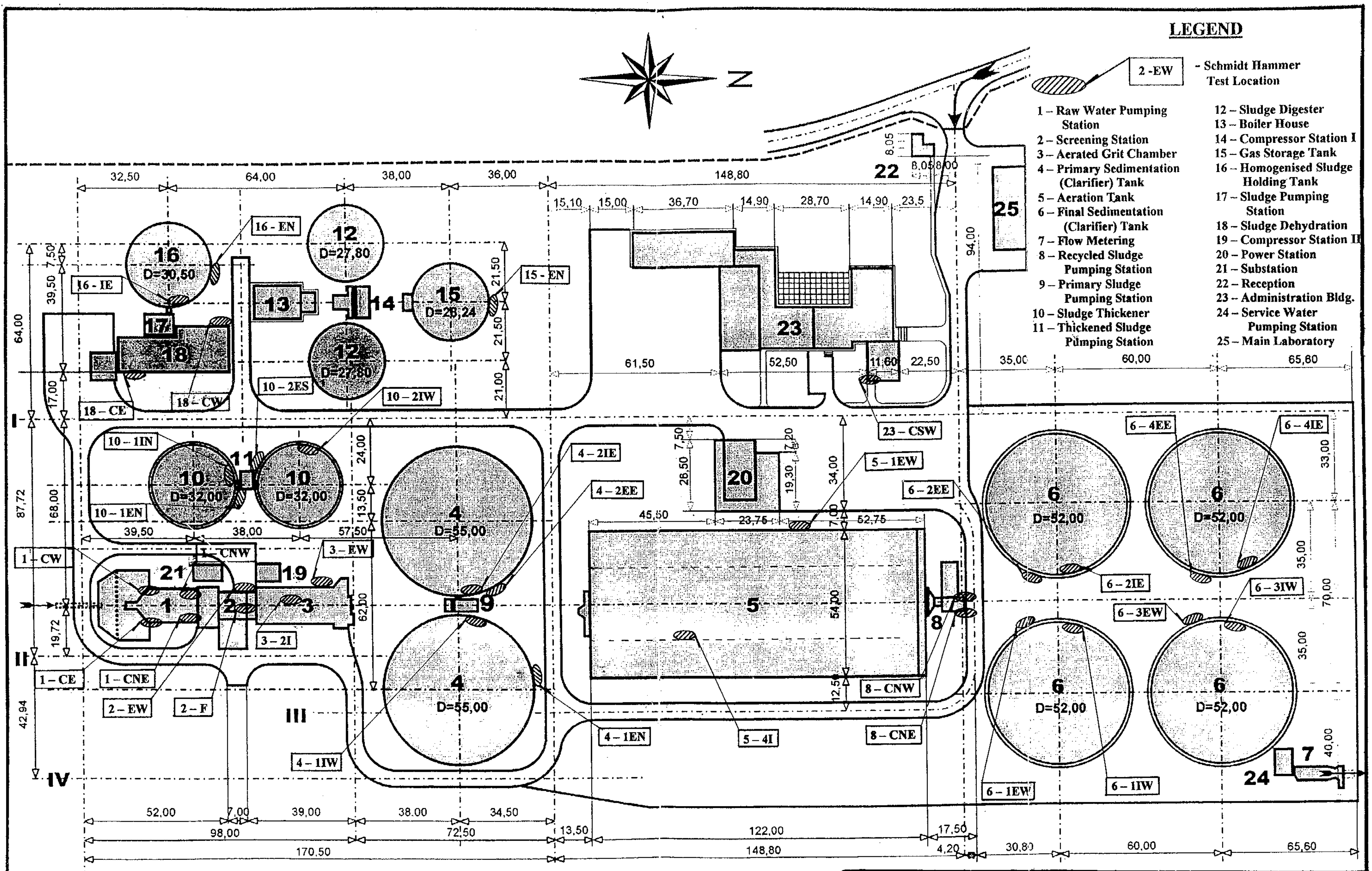
Table 2.2.1 CONCRETE STRESS STRENGTH TEST SUMMARY

No.	Facility No.	Name of Facility	Structure Member	Rebound Number, R	Cube Compressive Strength, W_m (kg/cm²)	Cylinder Compressive Strength, Zm (kg/cm2)
1/34	1	Raw Water Pumping Station	1 – CW	43	469	399
2/34			1 – CE	41	432	367
3/34			1 – CNE	44	488	415
4/34			1 – CNW	41	432	367
5/34	2	Screening Station	2 – EW	45	507	431
6/34			2 – F	39	395	336
7/34	3	Aerated Grit Chamber	3 – EW	55	703	598
8/34			3 – 2I	48	565	480
9/34	4	Primary Sed. Tank 1	4 – 1EN	37	360	306
10/34			4 – 1IW	39	395	336
11/34		Primary Sed. Tank 2	4 – 2EE	36	342	291
12/34			4 – 2IE	41	432	367
13/34	5	Aeration Tank	5 – 1EW	44	488	415
14/34			5 – 4I	36	342	291
15/34	6	Final Sed. Tank 1	6 – 1EW	42	450	383
16/34			6 – 1IW	40	413	351
17/34		Final Sed. Tank 2	6 – 2EE	49	548	496
18/34			6 – 2IE	43	469	399
19/34		Final Sed. Tank 3	6 – 3EW	41	432	367
20/34			6 – 3IW	38	377	320
21/34		Final Sed. Tank 4	6 – 4EE	51	623	530
22/34			6 – 4IE	39	395	336
23/34	8	Recycled Sludge P.S.	8 – CNE	42	450	383
24/34			8 – CNW	44	488	415
25/34	10	Sludge Thickener 1	10 – 1EN	39	395	336
26/34			10 – 1IN	41	432	367
27/34		Sludge Thickener 2	10 – 2ES	49	584	496
28/34			10 – 2IW	41	432	367
29/34	15	Gas Storage	15 – EN	44	488	415
30/34	16	Homo Sludge Holding Tank	16 – EN	44	488	415
31/34			16 – IE	55	703	598
32/34	18	Sludge Dehydration	18 – CW	49	584	496
33/34			18 – CE	40	413	351
34/34	23	Admin. Bldg.	23 - CSW	48	565	480

Table 2.2.2 COMPRESSIVE STRENGTH AS A FUNCTION OF THE REBOUND NUMBER

Rebound Number, R	14 – 56 Days Concrete			14 – 56 Days Concrete		
	Cube Compressive Strength, W_m			Cylinder Compressive Strength, Z_m		
	Kg/cm^2	N/mm^2	psi	Kg/cm^2	N/mm^2	psi
36	342	33.5	4,860	291	28.5	4,140
37	360	35.3	5,120	306	30.0	4,350
38	377	37.0	5,360	320	31.4	4,550
39	395	38.7	5,620	336	33.0	4,780
40	413	40.5	5,870	351	34.4	4,990
41	432	42.4	6,150	367	36.0	5,220
42	450	44.1	6,400	383	37.6	5,450
43	469	46.0	6,670	399	39.1	5,680
44	488	47.9	6,940	415	40.7	5,900
45	507	49.7	7,210	431	42.3	6,130
46	526	51.6	7,480	447	43.8	6,360
47	546	53.5	7,770	464	45.5	6,600
48	565	55.4	8,040	480	47.1	6,830
49	584	57.3	8,310	496	48.6	7,050
50	604	59.2	8,590	513	50.3	7,300
51	623	61.1	8,860	530	52.0	7,540
52	643	63.1	9,150	547	53.6	7,780
53	663	65.0	9,430	564	55.3	8,020
54	683	67.0	9,710	581	57.0	8,260
55	703	68.9	10,000	598	58.6	8,510

Source: Proceq SA Switzerland, Schmidt Concrete Test Hammer Manual



Date : Nov. 1999 Scale : As shown	THE FEASIBILITY STUDY ON THE WASTEWATER TREATMENT PLANT OF SARAJEVO SCHMIDT HAMMER TEST SITE PLAN	Figure 2.2

(2) Results & Evaluation

Compressive strength results are summarised in **Table 2.2.3** and presented in detail in the **IMK Report - Appendix F.**

Table 2.2.3 – SUMMARY OF CONCRETE STRENGTH TESTS

Structure	Element	Characteristic Concrete Strength (N/Mm2)	Concrete Grade (MPa)
5. Aeration Tank	Walls	32.7	30
	Bottom slab	27.2	25
3. Grit Chamber	Walls	31.7	30
	Bottom slab	35.8	35

Compressive tests indicate that concrete compressive strength is within the range of 20 to 40 MPa normally used for structural applications. Density tests indicate that concrete is "Normal Density" typically 2,400 kg/m3.

2.2.4 Steel – Tensile Stress Test

(1) Procedure

Extraction and testing was performed on reinforcing steel to determine tensile strength characteristics. Three samples were extracted from 6 locations in walls and bottom slab of the grit chamber and aeration tank:

- A1 and A2 directly from the walls of the aeration tank where steel was exposed ,
- A3 from the core sample taken out of the bottom slab of the aeration tank
- A4 and A5 directly from the walls of grit chamber where steel was protected by concrete cover
- A6 from the core sample taken out of the bottom slab of the grit chamber

Samples from locations A1, A2, A3, A4, A5 were prepared and tested in accordance with ASTM standards using an Amsler universal testing machine. Samples were tested to provide yield strength and ultimate strength. Elongation was measured to provide stress strain curves.

Samples from location A6 could not be shaped for testing in the Amsler machine therefore they were tested using the BRINELL hardness method to provide ultimate strength.

(2) Results & Evaluation

Visual inspection of the specimens after extraction and during sample processing indicates that corrosion is insignificant and there is no loss of cross sectional area.

Test results are summarised in **Table 2.2.4** and presented in detail in the **IMK Report - Appendix F**.

Table 2.2.4 – SUMMARY OF TEST RESULTS ON REINFORCEMENT STEEL

Specimen	Dia. (mm)	Designation	Yield Strength (N/mm2)	Ultimate Strength (N/mm2)	Strain on breaking (%)
A1 walls, aeration	25	GA – deformed bars	283.03	405.33	24.52
A2 walls, aeration	18	GA- deformed bars	279.7	425.13	28.73
A3 – floor aeration	9	MGA (welded wire fabric)	N/A	688.43	10.00
A4 – walls grit	12	GA	330.50	429.53	14.75
A5 – walls grit	12	GA	349.83	441.51	21.25
A6 – floor grit	12	GA	N/A	503	N/A

Deformed steel bars were used as reinforcement in walls. Reinforcement used in slabs is welded wire fabric.

Test results indicate that deformed bars are nominal grade GA 240/360 corresponding to the following characteristics:

- Yield strength = 240 N/mm2
- Ultimate strength = 360 N/mm2
- Ultimate Strain = 18%

Samples taken from aeration tank floor slab are of a higher-grade welded mesh MGA that has the following nominal characteristics:

- Yield strength = 500 N/mm2
- Ultimate strength = 560 N/mm2
- Ultimate Strain = 6%

In general the steel is of acceptable quality and in good condition. Steel corrosion is insignificant even in areas where it is exposed without cover.

2.2.5 Sludge Piping Material Tests

(1) Procedure

Sludge wasted from the recycle pumping station and the primary sedimentation tanks is conveyed to the thickeners through buried steel pipelines. In order to assess the condition of these pipelines samples where extracted at 4 locations. Examination consisted of, measurement of wall thickness, internal pipe diameter, and visual inspection to determine degree of encrustation and corrosion. Samples where tested using the BRINELL method to obtain ultimate strength.

(2) Results and Evaluation

Pipes from all four locations are in excellent condition and look like new. There is no corrosion of encrustation.

Nominal pipe diameters and thickness are as follows:

- C1, pipe from primary sludge pumping station to thickeners□ 230x 5.5
- C2, pipe form thickeners to digesters □ 160x 3.5
- C3, pipe from digesters to sludge holding tank □ 220 x 7
- C4, pipe from sludge re-cycle pumping station to primary tanks □ 230x 5.5

The average ultimate tensile strength ranged from 530 N/mm2 to 549 N/mm2. Based on standard JUS C.B0.500, the steel is classified as CN 36-B_2, general-purpose structural ductile steel.

2.3 LEAKAGE TEST

A visual inspection of the structures carried out during the first stage of the study revealed that most of the structures had previously experienced significant cracking and leakage problems. It is apparent that many attempts were made to seal the cracks and leaks from the outside using epoxy. Serious concerns about the effectiveness of repairs and further deterioration of the structures prompted the need to carry out tests for liquid retention.

(1) Procedure

Tests for liquid retention were performed on the following structures:

- No.3 grit chamber,
- No.4 two primary sedimentation tanks,
- No.5 aeration tanks, and
- No.6 four secondary sedimentation tanks.
- No.15, gas storage tank

Time constraints made it impossible to test every structure therefore only the ones representing the largest volumes were selected. Ideally the digesters should have been tested however it was not possible to do so because they are partly full of digested sludge. The sludge thickener tanks and the sludge holding tank were not tested because it was apparent from the visual inspection (walls are above grade) that these structures leaked extensively in the past and will require extensive leak sealing repairs to restore liquid tightness.

The local firm of USB Kedley Doo was hired to fill the tanks with water and take measurements. In addition to the contractor's work, the gas storage tank was filled by ViK and tested by JICA study team members in the weeks that followed completion of the contractor's work

Leakage tests were carried in accordance with British Standard Code of Practice for Design of Concrete Structures Retaining Aqueous Liquids (BS 8007 section 9). Stabilisation and measurement periods for each structure were shortened from the recommended 1-week period to 4 days to accommodate the compressed schedule.

Each structure was filled at a uniform rate to the normal maximum level by pumping water from the Miljacka River. When first filled, the liquid level was maintained by the addition of more water for a minimum of 4 days while absorption took place. After the stabilising period the drop in surface water level was recorded at 12-hour intervals for a minimum test period of 4 days. The drop in level was adjusted for rainfall and evaporation.

(2) Results and Evaluation

Although it is common for water retaining structures to be constructed of reinforced concrete they are never completely watertight because concrete naturally absorbs and then through evaporation, loses water. According to standard BS 8007 a structure can be considered watertight if the total drop in surface level does not exceed 1/500th of the average full tank depth or 10mm over the test period. The extent of absorption and leakage will depend on mix proportions used and the quality of construction. Where there are imperfections in the concrete, such as cracks or voids, water leakage can be substantial

Data and calculation sheets tabulated by the local contractor for the leakage test are presented in **Appendix B** and results are summarised as follows:

i. The grit chamber leaked at construction joints located between the outlet chamber and connections to outlet conduits. Several large cracks in the end wall allow water to leak in large quantities into the by-pass.

ii. The primary sedimentation tanks leaked extensively at expansion joints and at the horizontal construction joint that runs along the full circumference of the tank.

iii. The aeration tanks leaked but only a few large leaks were visible on the outside of the structure. Only a few of the previously repaired cracks were found to leak and only a few expansions showed signs of leakage. It is highly probable that much of the water leaked out the expansion joints of the bottom floor slab. Attempts to fill only one tank failed because leakage through the middle separation wall was too high. Heavy leakage was also observed through joints and cracks in the influent channel located between the two tanks. Internal migration of water from one tank to another is only a problem if one tank is kept empty and out of service.

iv. The secondary sedimentation tanks leaked but the location could not be determined because the tanks are buried. Extensive leakage was observed at the inlet structure located at the end of the aeration tank. Large cracks in the sidewalls and along the front of each sluice gate leak extensively.

Leakage in all structures was substantially more than acceptable for liquid retaining structures. There are many possible reasons for the occurrence of leakage. The most common causes are:

- cracks caused by shrinkage
- voids below the reinforcement due to plastic settlement
- voids below water bars at expansion joints
- unsatisfactory construction joints
- failure to adequately grout up holes provided for form work ties
- honeycombing or voids due to poor compaction or grout loss

Identifying the cause of leakage is never quite straightforward, as the place where liquid enters is seldom where leakage is apparent on the surface. Where possible, location on the exterior of leakage through cracks, expansion joints and construction joints was documented during the visual survey to provide an approximate idea of the extent of repair works that will be required.

2.4 COMMENTS ON DESIGN

(1) Design

All liquid retaining structures are reinforced concrete. The structures were designed by the local consulting engineering firm of Bosna and constructed by a local contractor.

Design is based on limit states with the following values used in structural calculations:

Allowable compressive strength of concrete:	30 MPa
Allowable tensile strength of steel:	360 MPa
Reinforcement cover:	40 mm
Ground water depth:	max = 485.8, mid = 485.5, min 485.0
Soil bearing capacity:	11.3 N/cm^2

The water table is high and most of the structures are subject to groundwater pressure. Design calculations show that structures have sufficient dead weight to prevent flotation when empty.

Walls of rectangular and circular tanks are designed to act as cantilevered retaining walls with expansion joints between individual wall sections and floor slabs. Walls are designed to prevent overturning and bearing failure under all operating conditions.

Floor slabs appear to have been cast on a mud slab to provide uniform support with a plastic slip layer to reduce friction. Structural calculations for floor slabs show that uplift pressure was taken into account in the design of reinforcement by placing steel in the top and bottom of the slab.

Structural design calculations (in Bosnian), drawings and reinforcement details for 4 structures have been collected as data for future reference at the design stage:

- pumping station
- aerated grit chamber
- primary sedimentation tanks
- aeration tank

2.5 INSPECTION & APPRAISAL

2.5.1 Introduction

The visual condition survey is perhaps one of the most important aspects of any structural investigation. Combined with the results of materials tests it aims to provide information on the types, extent and seriousness of visible defects.

Each civil structure was inspected to assess the extent and severity of damage and quantify necessary repairs. Inspection was carried out during hydraulic leakage tests to spot leaks. Inspection focused in locations where signs of distress were evident, where previous repairs have been made and where surfaces are not buried or hidden by architectural finishes. The survey notes condition of concrete surfaces, cracks, expansion joints and signs of corrosion. Although not structural in nature other civil related items needing repairs were also noted: ladders, railings, stairs, sluice gates, thermal insulation on digesters and corrosion protection of steel roof on gas holder. Visual condition survey sheets for all liquid retaining structures and photographs documenting typical defects or rehabilitation needs are presented in **Appendix G**.

Typical structural defects encountered during the survey and their probable causes are listed in **Table 2.5.1**. Observed defects that are common to all liquid retaining structures are summarised as follows:

- Leaking expansion joints
- Leaking construction joints
- Cracks through wall sections resulting in leakage
- Inadequate concrete cover resulting in corrosion of reinforcement
- Weathering of exposed concrete surfaces

The general nature of these defects, their cause and an assessment of required remedial works are presented in the following sections.

2.5.2 Expansion Joints

Leakage was observed at many expansion joints. The problem occurs at all structures but was most severe at primary sedimentation tanks were water was gushing rather than dripping.

Table 2.5.1 - Summary of typical concrete defects in liquid retaining structures

No.	Defect	Location	Probable causes
1	leaking expansion joints	Walls of all liquid retaining structures	deteriorated seal, torn water bar, voids around the water bar
		Walls and floor of all overflow channels	
2	leaking construction joints	horizontal joint along full circumference of all circular basins; usually at base.	poor workmanship, absence of water bar or defective water bar
		horizontal joint between floor and walls of all overflow channels	
		vertical joints in walls of all inlet and outlet structures adjoining grit chamber, primary clarifiers, and aeration tank	
3	Deep cracks through wall sections resulting in leakage	walls of all liquid retaining structures	Shrinkage cracks and thermal movement
		walls of all overflow channels	
		walls of gas holding tank	
4	Cracks at 45^0 angle and occasionally in parallel	west walls of aeration slab symmetrically located either side of aerator slab connection	tension or compression along line of force
5	Inadequate cover over reinforcement resulting in corrosion and spalling of concrete	interior walls of primary clarifiers, aeration tank, secondary clarifiers, sludge thickeners, and sludge holding tank.	poor workmanship
		South and west face of columns supporting surface aerators	
6	Frost damage resulting in spalling concrete	top of all slabs and flat surfaces exposed to weather (walkways, aerator slabs, top of walls & stairs)	inadequate drainage and no air entrainement in concrete
		bottom of aerator slabs and top of columns at water level	splash damage
7	Weathering of exposed concrete	all exposed concrete wall surfaces	very porous finish not sealed to prevent moisture penetration

Leakage through expansion joint in wall

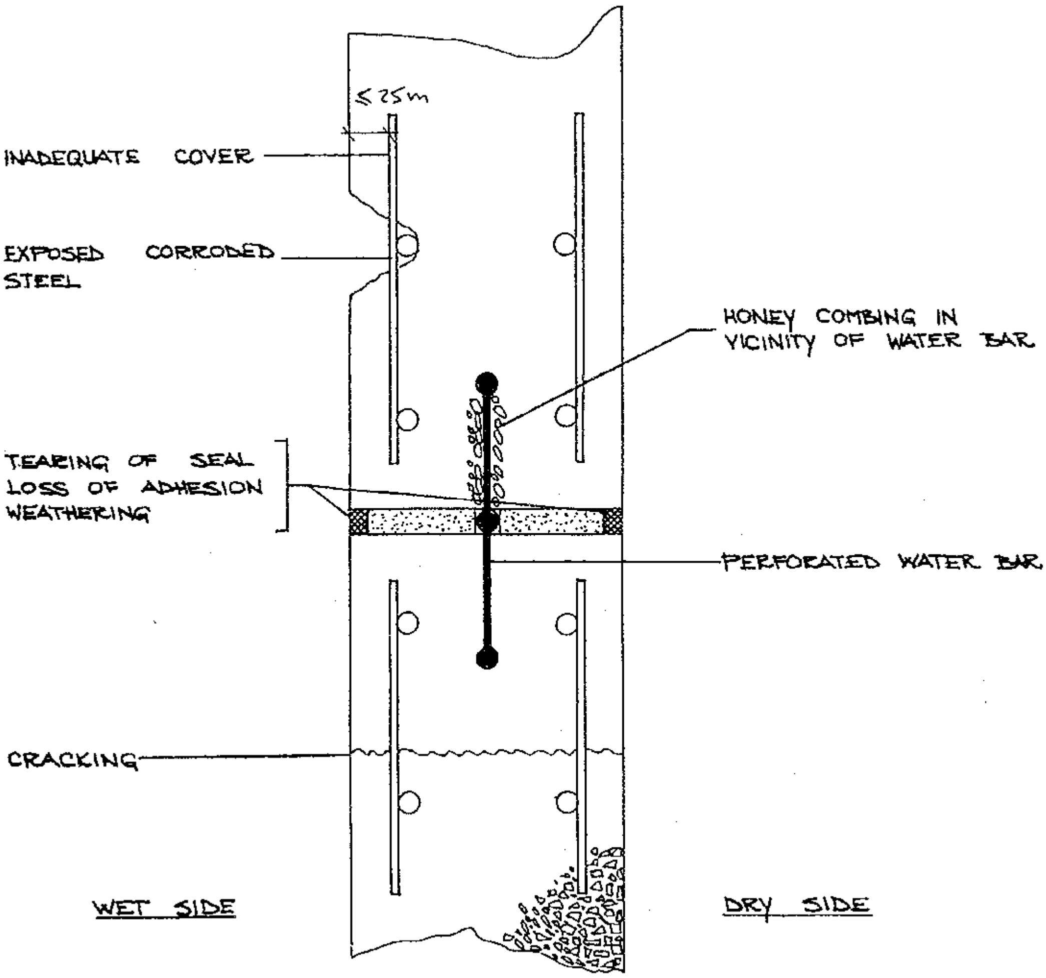
Typically, expansion joints consist of a gap containing a compressive filler material (e.g. expanded polystyrene) and finished with a sealer (typically a mastic substance). Expansion joints also incorporate a water bar. Leakage of water through expansion joints is a frequently occurring problem and may be caused by any of the following defects:

- Rupture of sealant
- Detachment of the sealant from the concrete
- Puncture of the water bar
- Defects in the concrete alongside the joint

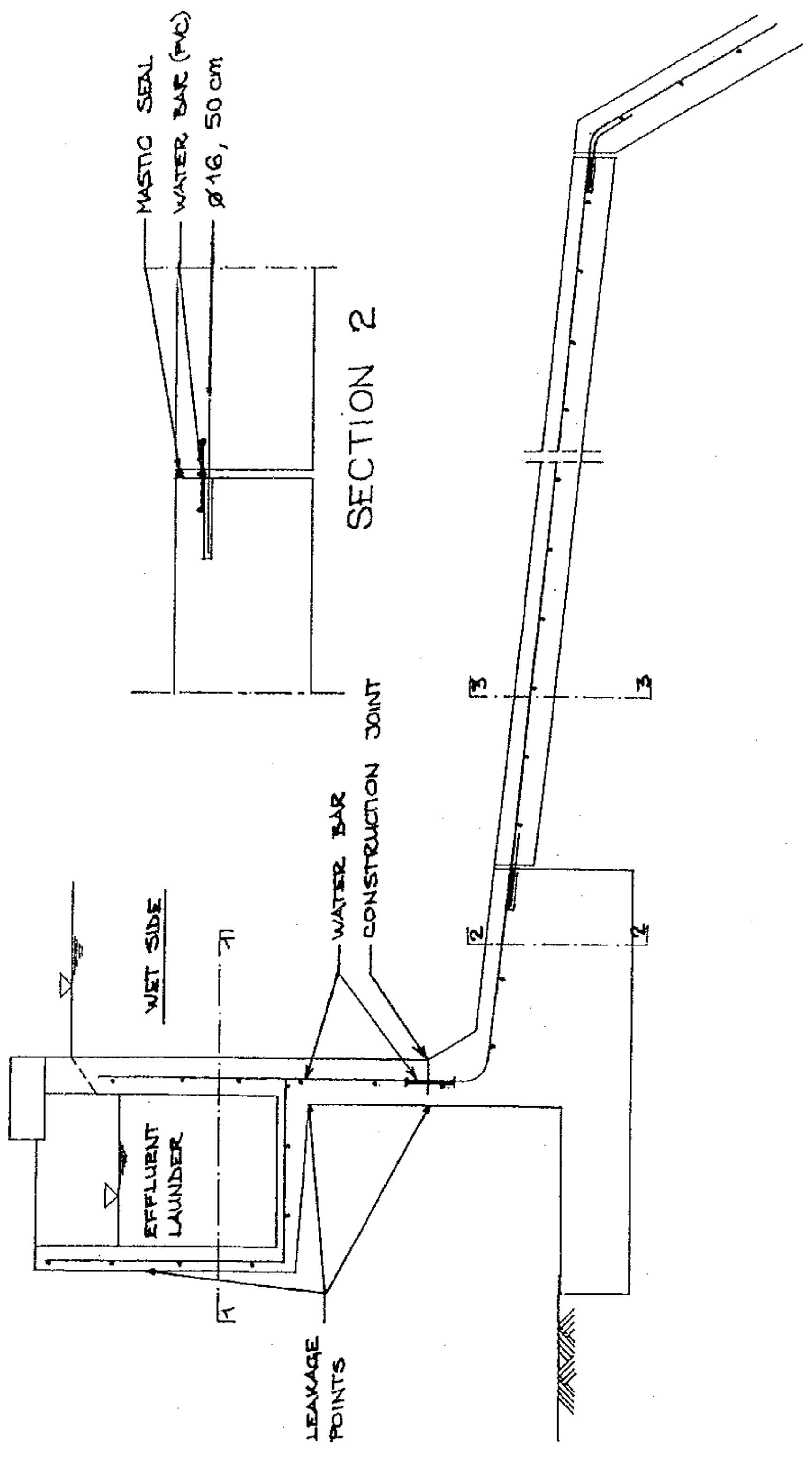
These defects, illustrated in **Figure 2.5.1**, are normally the result of poor control during construction and are very difficult and costly to repair.

Water bars used in the construction of all water retaining structures on site appear to be polyvinyl chloride strips 250mm wide with a central bulb. In walls the water bar is located centrally following common construction practice. Typical water stop details for the structures on site are shown in **Figure 2.5.2** and **Figure 2.5.3**. It is important for walls to be sufficiently thick to allow proper compaction of the concrete around the water bar. Wall thickness wherever practical should be at least 250mm thick. The walls on main structures appear to be sufficiently thick to ensure good compaction. Effluent launder wall thickness varies from 150 to 200 and it is likely that good compaction could not be achieved which might explain why all joints in effluent launders leak.

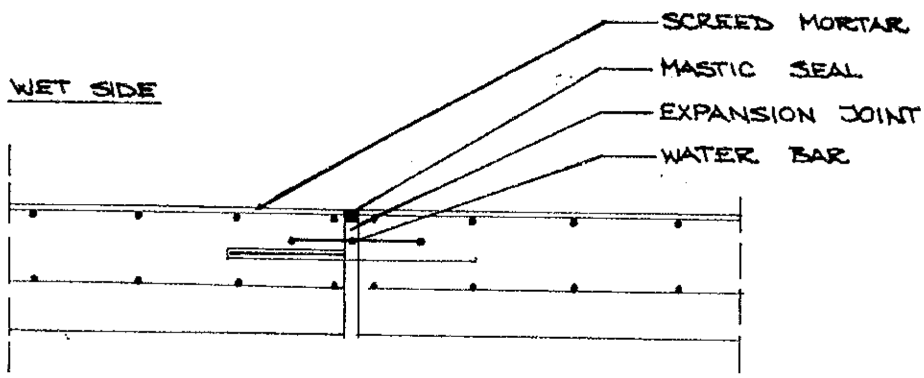
In floors the water bar is located in the middle depth. It is usually preferable to place the water bar below the main floor slab because it is difficult to ensure proper compaction of the



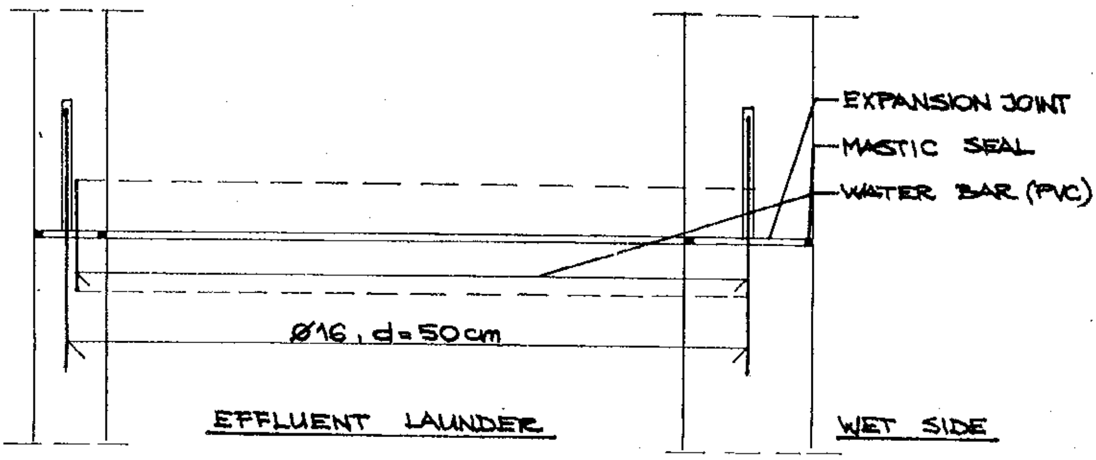
Date : Nov. 99 Scale: Not to scale	THE FEASIBILITY STUDY ON THE WASTEWATER TREATMENT PLANT OF SARAJEVO TYPICAL DEFECTS IN LIQUID RETAINING STRUCTURES	Figure 2.5.1



Date : Nov. 99 Scale: Not to scale	THE FEASIBILITY STUDY ON THE WASTEWATER TREATMENT PLANT OF SARAJEVO TYPICAL WALL & FLOOR SECTION FOR CIRCULAR TANKS	Figure 2.5.2



SECTION 3
CROSS SECTION THROUGH FLOOR SLAB



SECTION 1
PLAN VIEW OF EFFLUENT LAUNDER

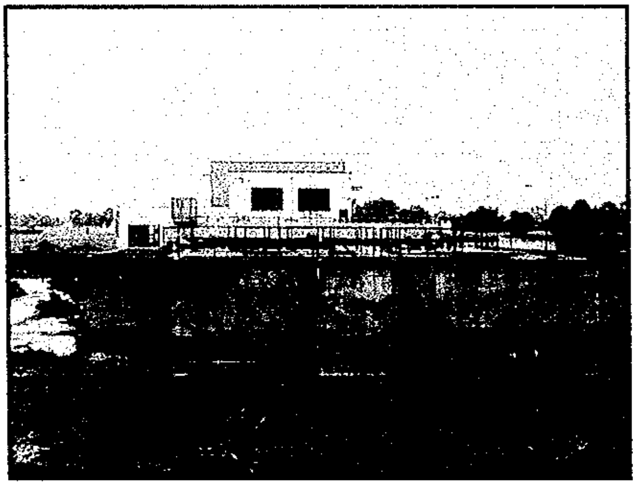
Date : Nov. 99 Scale: Not to scale	THE FEASIBILITY STUDY ON THE WASTEWATER TREATMENT PLANT OF SARAJEVO EXISTING EXPANSION JOINT – DETAILS	Figure 2.5.3

concrete around a horizontal centrally placed water bar. Given the evidence of poor workmanship in other areas of the structures it is highly likely that compaction around the water bar was poor and that the water bar is not liquid-tight.

Identifying the location or cause of leakage is never quite straightforward, as the place where liquid enters is seldom where leakage is apparent on the surface. It is impossible to assess with precision if a joint should be repaired or will continue to perform well without repair. Since it is quite likely that most joints leak to some degree it is better to treat every joint as a potential source of leakage.

2.5.3 Construction Joints

Construction joints appear in many locations on all structures. Many of these joints contribute to significant leakage, which is particularly noticeable at the grit chamber outlet, and the outlet of the aeration tank



Previously repaired horizontal construction joint at grit chamber

Construction joints have generally been provided when concrete operations were suspended during construction. Many construction joints appear in areas where the complexities of formwork made it easier for the contractor to place concrete in separate stages. The joints at junctions between horizontal surfaces and vertical walls are a typical example.

To obtain a watertight joint it is important to obtain a good bond between the old concrete and the new concrete when it is compacted against it. It appears that this bond was not achieved since most horizontal construction joints leak extensively. This type of defect is the result of poor design details, inadequate sight supervision and poor construction practices.

The joint between the kicker and wall panel in circular tanks is common to all liquid retaining structures on site. This joint is supposed to have a water bar installed to prevent leakage but evidence of extensive repairs at this point suggests the water bar was probably never installed.

2.5.4 Cracks

Structures that retain liquids at the treatment plant are subjected to severe exposure and require special consideration to ensure durability and control cracking.

The presence of deep vertical cracks is predominant on all exposed wall surfaces and most numerous on the outside walls of effluent launders in the sedimentation tanks and sludge thickeners.

Vertical cracks in walls and effluent launder

The extent of the cracking indicates that there is insufficient reinforcing steel to control the tensile stresses created by shrinkage and temperature movement.

The temptation to fill every crack in a reinforced concrete structure must be resisted because filling does not always improve the situation. It is generally safe to fill cracks where the cause for cracking is no longer active. Non movement cracks can therefore be filled using the epoxy injection method. Cracks subjected to seasonal or diurnal movements are a special case. These cracks should be filled with a material that is flexible enough to accommodate the expected movement. All cracks should be filled from the liquid side of the structure to provide an effective seal.

2.5.5 Corrosion of Reinforcement

Corrosion of reinforcement is widespread and occurs predominantly at the liquid face of walls. In many large areas rust stains appear at the surface of the concrete and follow the line of reinforcement. Material tests show that corrosion has not yet resulted in the loss of steel from the reinforcing bars. Loss of section was detected in small areas of the sludge holding tank were steel is exposed.

Certain factors are necessary before the steel reinforcement will corrode:

- water or dampness
- oxygen
- destruction of the passivity layer that protects the steel from corrosion

Inadequate cover and corrosion of reinforcement

Adequate cover is extremely important in protecting reinforcement. The requirements of modern codes of practice in respect of cover are adequate only if the cover is of dense well-compacted concrete otherwise the concrete will carbonate and so lose its protective capacity. As confirmed by testing, the carbonation front has already advanced to a depth of 20 mm. As observed on site, the cover is inadequate on all interior wall surfaces (usually less than 25 mm and in many cases only a few mm) and the concrete is quite porous. These two factors have contributed to the corrosion observed on site. There is a significant risk of further and severe deterioration.

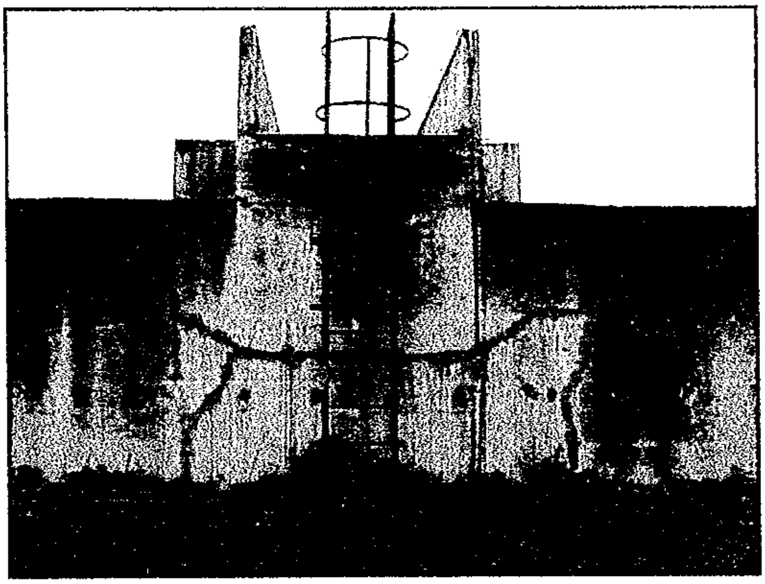
2.5.6 Weathering of Exposed Surfaces

Sanitary engineering structures normally require special attention for durability. Specifications for concrete mix design and for construction should be drawn up to provide for dense, impermeable concrete which will resist to naturally occurring chemicals and have a smooth well formed surface finish. Dense, well-compacted concrete is rarely affected by frost.

Concrete surfaces on all structures are porous, rough and do not repel water. Exposure conditions and severe weather causing freeze thaw cycles have affected the durability of concrete on site. Concrete on all flat surfaces such as floor slabs and top of walls where water has a tendency to pond have suffered severe damage. In several cases the damage has progressed to complete disintegration to deeper layers.

2.5.7 Cracks in Aeration Tank Walls

The east wall of the aeration tank exhibits a cracking pattern that indicates a structural deficiency. The pattern is observed at every point where the concrete walkway is connected to the top of the wall. The following photograph depicts the typical condition.

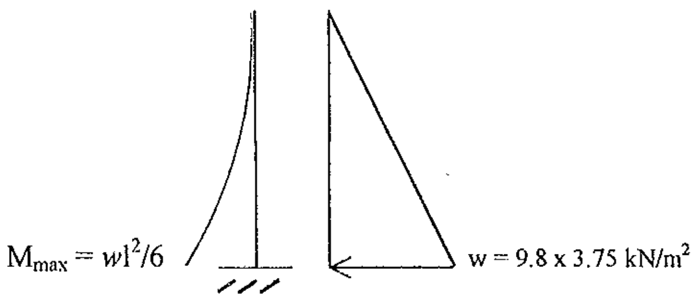


East wall of aeration tank

The cracks form a 45-degree angle starting at from the top of the wall extending down towards the centre where they become horizontal. In the middle of the wall span between two access ladders there is a long vertical crack.

At first it was believed that these cracks might be caused by vibration from the surface aerators. This idea was rejected after testing of the aerators indicated that vibration is insignificant and could not cause this type of cracking pattern. Understanding the failure mechanism is important in order to propose a suitable repair. Simply sealing the cracks would not be effective since the forces that caused them in the first place will still be present and new cracks will form.

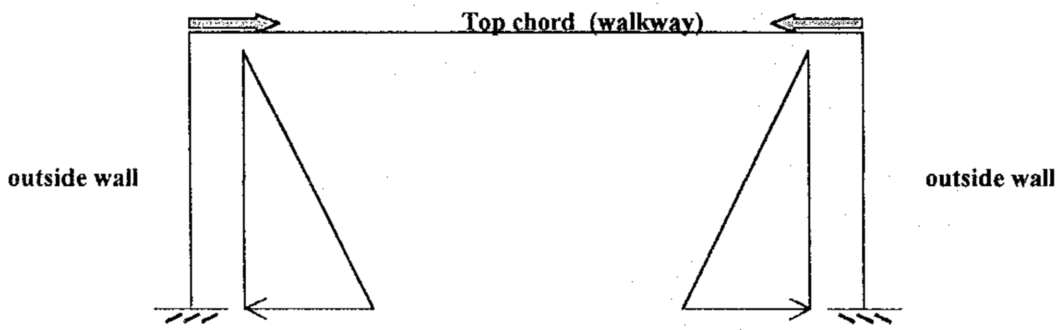
A review of design calculations shows that the walls were designed, as is common practice, for cantilever action with primary bending in the vertical plane.



Cantilever wall

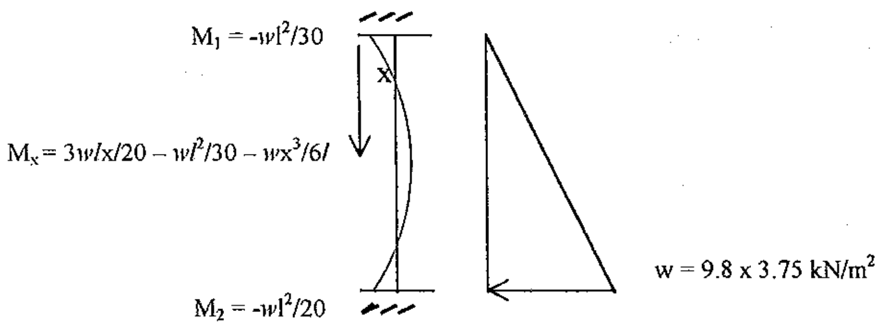
Maximum bending moment under this assumed condition is 93 kN.m and occurs at the base of the wall on the wet side of the tank. Vertical steel indicated on the drawings is □18 at 200 mm spacing and is adequate for resisting moments under this condition.

The cantilever model is not valid where the concrete walkway is attached to the top of the wall. The observed cracking can be explained by a simplified model assuming the concrete walkway acts as a top chord tying the two outside walls together as illustrated below.



The top chord prevents the walls from bending out at the top as they were designed for and the rigid connection between wall and walkway induces positive bending moments on the outside face in two locations:

- Bending in the horizontal plane with a maximum in the middle span
- Bending in the vertical plane with negative moments at the top and bottom of the wall and positive moments approximately 2 m from the top.



Wall with rigid connections

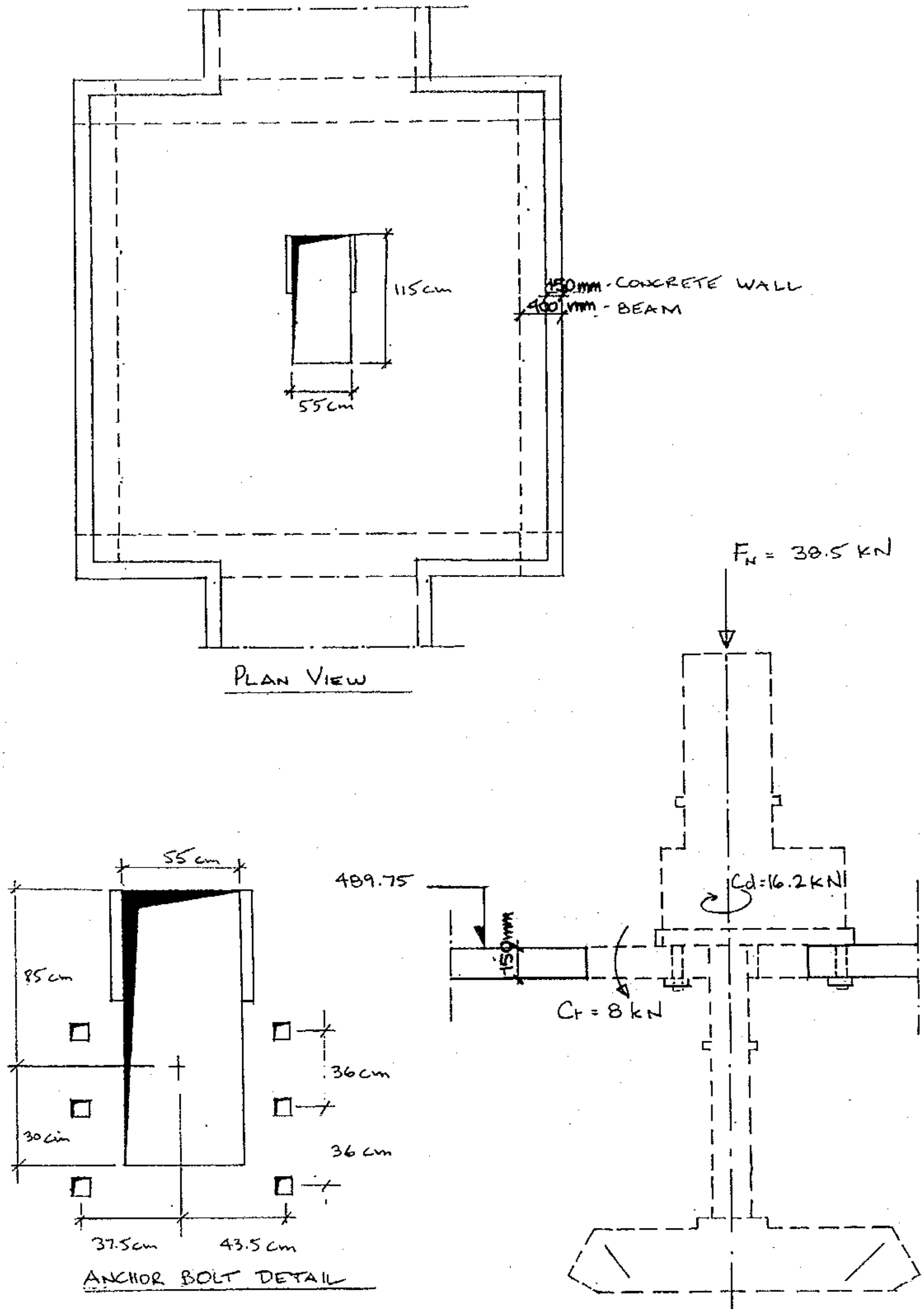
Bending moment M1 and M2 are smaller than in the simple cantilever model therefore reinforcement on the inside face of the wall is adequate to resist bending. However reinforcing steel on the outside face is insufficient to resist positive bending moments. Reinforcing steel on the outside face is □8 at 100mm centres in the vertical direction and □8 at 200mm centres in the horizontal direction. The maximum positive bending moment occurs at 2.05 m from the top and is 11.08 kN.m. The reinforcement is insufficient to resist bending moments resulting in tension cracks under load.

These two models are simple assumptions and neither one accurately describes the actual stress and shear patterns in the wall. Precise analysis would require finite element modelling of the walls to determine how the wall plates actually behave under load. Nevertheless, for the purposes of finding an appropriate repair strategy the simplified assumptions are sufficient to confirm that filling these cracks with epoxy grout will not solve the problem. It is important to remove the restraint provided by the walkway and allow the wall to function as it was intended (i.e. as a cantilever wall). The change can easily be made by cutting out the existing slab and replacing it with an open-grate galvanised metal walkway freely supported at the wall.

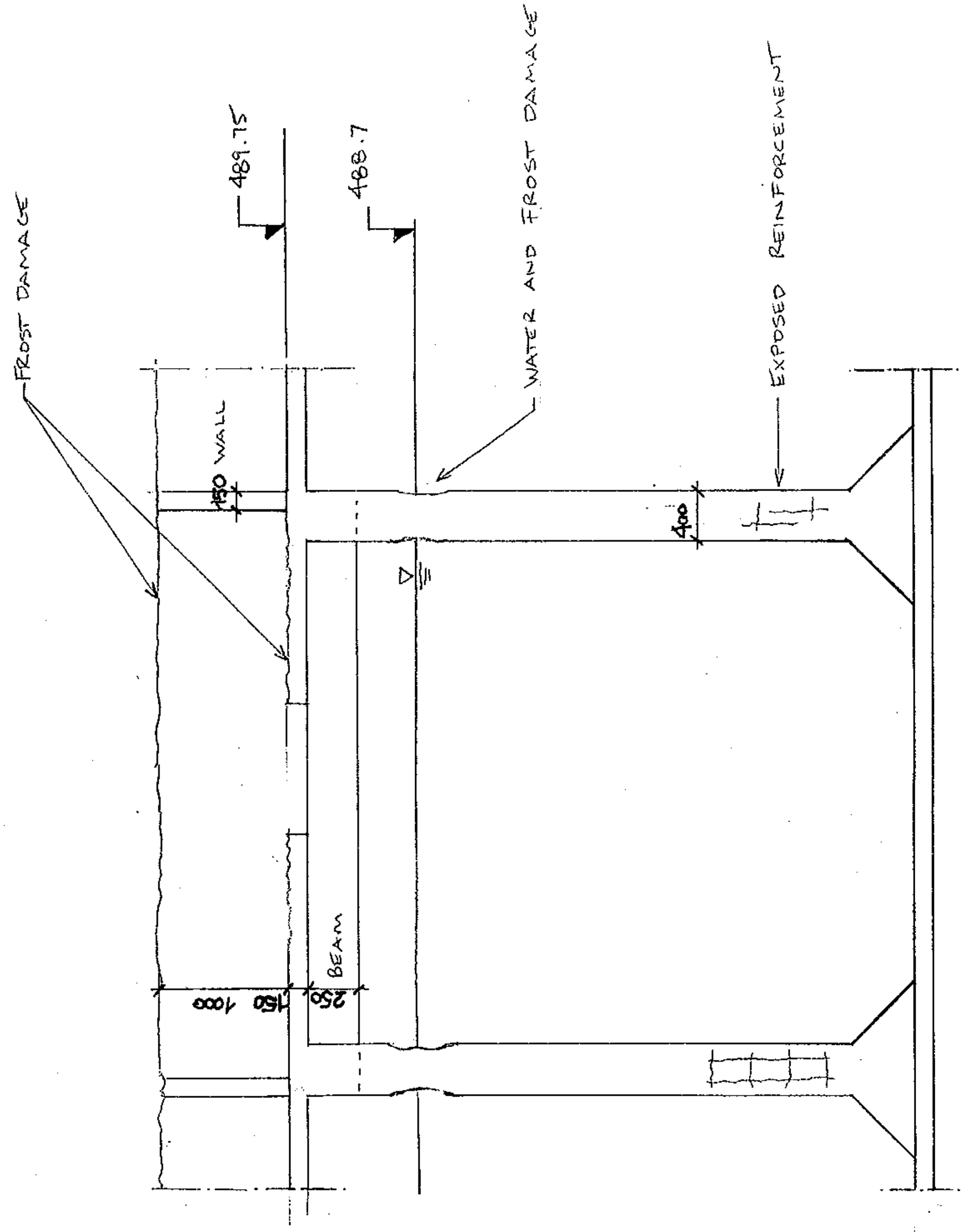
2.5.8 Surface Aerator – Slabs, Columns and Walkways

Plan and sectional views of the existing aerators are presented in **Figure 2.5.4** and **2.5.5**. Slabs and columns will need extensive reconstruction if the decision is made to keep the present surface aeration system. There are several problems observed:

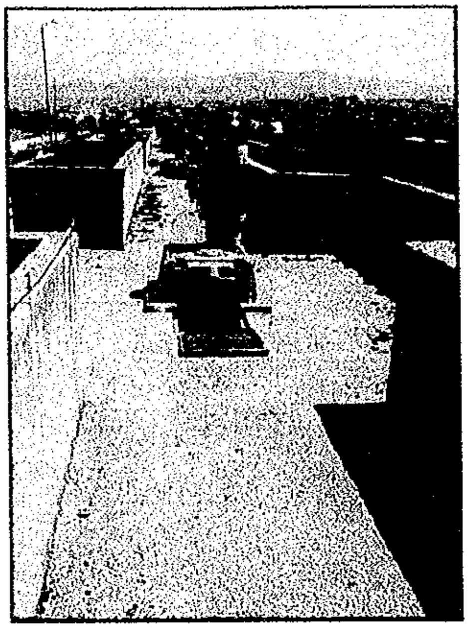
- installation of aerator anchor bolts through the slab creates stress points that cause cracking
- there is no pad for leveling screws
- There is no vibration isolation pad between the machine and the concrete.
- The concrete slabs and walkways are severely damaged by water and frost as a result of poor drainage. Reinforcement is exposed and corroded
- The concrete fence walls are severely damaged by water and freezing action. The reinforcement at the base of the wall is exposed.
- Columns are damaged at the water line by the action of turbulent water and freezing
- Reinforcement in columns on the south and west faces is corroded.



Date : Nov. 99 Scale: Not to scale	**THE FEASIBILITY STUDY ON THE WASTEWATER TREATMENT PLANT OF SARAJEVO** **SURFACE AERATORS – EXISTING SLAB, PLAN & DETAILS**	**Figure 2.5.4**



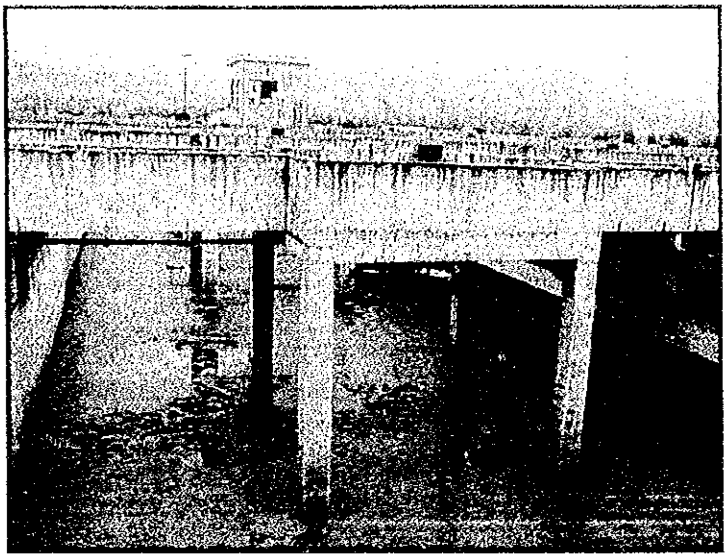
Date : Nov. 99 Scale: Not to scale	THE FEASIBILITY STUDY ON THE WASTEWATER TREATMENT PLANT OF SARAJEVO	Figure 2.5.5
	SURFACE AERATORS – EXISTING SECTIONAL VIEW	



Typical surface aerator slab

The existing 150 mm slabs are not worth rehabilitating since the damage is deep and the slabs are thin. Adding a new topping of sufficient thickness to protect the steel is not feasible because it would lift the surface aerator above the surface of the water and the shaft length cannot be adjusted.

The cover over reinforcing steel in columns is insufficient on the South and West face. Corrosion of the reinforcing steel has produced rust stains on the surface in line with the reinforcement. The same defect is observed at every column, always on the same two faces. Lifting hooks on the North side of every column indicates that the columns were pre-cast then lifted into place. The lack of cover is probably caused by poor form work during the fabrication of the columns.



Typical surface aerator slab & column

Corrosion is not yet severe and has not resulted in the loss of section. Therefore the steel should be exposed, cleaned and treated in the same way that is specified for the walls.

2.5.9 Digesters

Anaerobic digesters are hermetically sealed containers in which liquid sludge is heated to undergo biological fermentation. As a result of this process the sludge is stabilized and transformed into bio-gas.

It was impossible to inspect the interior of the digesters because they are still 2/3 full of sludge. The insulation on the outside of the digesters conceals the concrete making it impossible to inspect for cracks and other structural defects. Thermal insulation and roofing will need to be replaced entirely. The inside of the digesters will need to be cleaned and inspected to ensure that protective coating is intact. After cleaning and before remedial works, the digesters should be tested for liquid and air tightness.

2.5.10 Gas Storage Tank

The gas storage tank appears to be liquid tight although there are several cracks in the exterior concrete. The interior surfaces could not be inspected because the walls of the gas dome hide them. Inspection and any remedial works would require the complete removal of the dome.

The floating cover is steel and appears to be in good condition with only minor corrosion on the exterior. The inside surfaces of the tank could not be inspected but it is highly probable that the steel roof will need a new protective coating on the inside. The coating should be resistant to gas corrosion. During site inspections it was observed that the pressure relief valve at the top of the dome is broken allowing hot air to escape. This valve will need to be replaced to make the storage tank air-tight.

The water inside the dome is heated to prevent freezing of the water seal between the walls of the concrete and steel roof. Piping located in the floor slab circulates hot water from the boilers. This piping is probably corroded and should be replaced. The roof will need to be lifted for remedial works to take place. This operation is discussed in more detail in the main report under construction issues.

2.5.11 Primary Sedimentation Tanks - Footings

The footings on the primary sedimentation tank walls are only 0.5 meters below grade whereas frost penetration depth is at least 0.8 meters. Frost action result in movement of the structure and additional stresses that the structure was not designed to withstand. One visible result of excessive movement is failure (leakage) of the water bar in several expansion joints. It is therefore recommended to backfill around the primary sedimentation tanks in order to protect the footings from frost heavily.

2.6 CONCLUSION

The condition, assessed needs and proposed rehabilitation for each civil structure is summarized in **Table 2.6.1**.

In general the structures are safe and have sufficient strength to meet their intended use, however they show considerable signs of deterioration such as:
- weathering of all exposed surfaces,
- extensive cracking in walls with signs of leakage and previous repairs,
- inadequate cover over reinforcement, and
- Exposed and corroded reinforcement.

Based on the results of materials testing it would appear that materials used for construction have the properties required for good structural performance. Deterioration is not yet at an advanced stage but significant effort will be required to seal leaks, repair damage and protect against further damage. The structures could be put in service without repairs but corrosion would quickly lead to irreparable damage that will significantly shorten the life of the structures.

Widespread corrosion of reinforcement on the interior face of all tanks is a result of inadequate cover caused by poor workmanship. Corrosion has not yet reduced structural performance but some intervention will soon be required to prevent loss of reinforcement cross section and keep the structures in service. Carbonation has advanced to a significant depth and there is a high risk that corrosion will become more serious where cover is less than 25mm.

Flat concrete surfaces, prone to water ponding, are badly damaged by freeze-thaw cycles. It recommended that reinforcement on all interior walls of liquid retaining structures be treated to remove corrosion and covered with new concrete.

The leakage problem is substantial and widespread. Most of the visible leakage occurs at cracks, construction joints and expansion joints in walls and floors. Most of the previously repairs cracks seem to be holding water but several are showing signs of distress and some are beginning to leak again. All cracks and joints should be repaired from the liquid face to make them liquid tight. If they are not repaired wastewater will leak onto the ground creating a health hazard. Wastewater is chemically aggressive and when it leaks through cracks and joints it causes significant damage to the concrete and steel and may reduce the life of the structure.

Table 2.6.1 (1/9) - Scope of Rehabilitation for Civil Works

Facility Name	Structure	Condition Assessment	Recommended rehabilitation
1. Raw water pumping station	Inflow Gate Chamber	The concrete panels covering the chamber are damaged and difficult to remove for maintenance access.	Replace concrete cover with removable steel grating.
	Inflow gate	Plant operators confirm that the gate never operated properly since the day it was first installed. The guides appear to be damaged near the bottom and the gate cannot be fully closed.	The gate cannot be repaired. It will not be required after the new pre-treatment facility is constructed, therefore the gate should be removed.
	General	Steel railings around wet well are missing	Provide railings around perimeter.
		Concrete stairs leading up to the pump station control room are badly damaged by weathering. The cross sectional dimensions are inadequate and reinforcing steel is exposed and corroded.	Remove concrete stairs and replace with open grate galvanized steel stairs and landings, and railings.
	Wet well for screw pumps	Concrete pillars were constructed in front of screw pumps to prevent damage from large objects. These pillars trapped too many rags and debris and quickly became clogged resulting in a serious operating and maintenance problem.	Remove the concrete pillars and wire cage.
		There is provision for maintaining the lower bearing of each screw pump individually by inserting stop boards to isolate the flow. The stop boards are missing.	New stop boards are required (8)
2. Screening Station	Inlet structure	Sluice gates are in good condition but need maintenance	Replace packing and grease spindle
		The wide cross section causes low velocities which results in excessive deposit of sediments. These sediments block screens and create operating difficulties.	Reduce the cross sectional area by forming new channels. Improve hydraulic conditions by extending wing walls to direct flow towards screens.
3. Aerated Grit Chamber	General	Handrails and ladders are rusted.	Provide new handrails. Replace ladders with steel stairs.
		Access to the travelling bridge along the outside walls is inadequate	Provide open grate walkways and railings on both sides of the grit chamber.
		The travelling bridge cannot operate properly in the winter because the running surface on top of the wall is susceptible to freezing an snow accumulation.	Provide 100 mm air entrained concrete topping to accommodate heat tracing cable.

Table 2.6.1 (2/9) - Scope of Rehabilitation for Civil Works

Facility Name	Structure	Condition Assessment	Recommended rehabilitation
3. Aerated Grit Chamber	General	Concrete slab surfaces are damaged by frost. Reinforcing steel is exposed.	Remove all concrete walkways and replace with open steel gratings. Extend gratings over inlet and outlet wells.
	Silting basin walls	Exterior walls are exposed to weathering which leads to rapid deterioration of concrete surfaces.	Seal exposed concrete surfaces
		Sluice gates at outlet are in good condition but need maintenance	Replace packing and grease spindle
		The hydraulic leakage test confirms that leakage through cracks and joints is excessive. Most of the leakage occurs at horizontal and vertical construction joints in the outlet structure. Expansion joints appear to be water tight.	Seal all cracks and construction joints. Provide new seal in expansion joints.
4. Primary Sedimentation tanks	General	Steel ladders and rails are rusted. There is no access to the peripheral end drive of travelling bridge.	Provide steel stairs. Provide open grating walkway and railings beside overflow launder.
	Inlet structure	Wood stop boards at inlet are rotted	Provide new stop boards (2)
		The concrete slab supporting the gate actuators has failed and there is insufficient space for operating the sluice gate.	Replace with stronger slab and cover open wells with open grating to improve access space for operation of valve.
	Tank walls	The hydraulic leakage test confirmed that leakage through cracks and expansion joints in the wall and overflow launder is excessive. Several of the cracks that were previously repaired are leaking.	Seal all cracks and construction joints including any that were previously repaired. Repair expansion joints.
		Inside walls of tank have inadequate cover over reinforcement. Steel is corroded and exposed over most of the surface area.	Expose and treat all corroded reinforcing steel. Provide new concrete wall 150mm thick on inside face to increase cover and facilitate repair of expansion joints. Provide protective coating for high and low water levels.

Table 2.6.1 (3/9) - Scope of Rehabilitation for Civil Works

Facility Name	Structure	Condition Assessment	Recommended rehabilitation
4. Primary Sedimentation tanks	Tank walls	Footings are only 0.5 meters deep and are susceptible to frost heaving.	Damproof concrete and backfill around tanks 1m deep.
	Tank floors	The floor finish appears to be in good condition. The screed finish is cracked along the movement joint (normal) but is not delaminated. Leakage in floor joints is probable.	Remove existing screed mortar. Provide new expansion joint and 100 mm concrete floor over existing.
	Slab supporting the peripheral drive unit for scrapper bridge	The top surface of slab is rough. Supporting columns located next to expansion joints have shear failure.	Reconstruct columns and reinforce with additional shear steel.
	Overflow Channel	Leakage was observed at all vertical & horizontal expansion joints and several deep cracks	Seal all cracks and construction joints. Repair expansion joints.
	Outlet Structure	Leakage was observed at horizontal construction joints.	Seal all construction joints.
5. Aeration Tank	General	Steel ladders and rails are rusted. There is no direct access from one row of aerators to the next making operation and maintenance difficult.	Provide steel stairs and railings at inlet and outlet side along East and West elevation (4 total). Provide steel catwalk to interconnect aerators.
	Inlet structure	Concrete slab surfaces are damaged by frost	Remove loose concrete and finish with air entrained epoxy mortar
		Inadequate surface area for operations and maintenance	Cover intake structure wells with open steel grating
		The inflow weir is damaged	Install new weir plate
		The wood stop boards used to isolate the flow of primary influent are rotted.	Provide new stop boards (5)
	Tank walls	The hydraulic leakage test confirms that leakage through cracks and expansion joints is excessive.	Seal all cracks and construction joints. Repair expansion joints.
		Inside walls of tank have inadequate cover over reinforcement. Steel is corroded and exposed over 40% of the surface area.	Expose and treat all corroded reinforcing steel. Provide new concrete wall 150mm thick on inside face to increase cover and facilitate repair of expansion joints. Provide protective coating 1 m either side of high and low water levels.
		The rigid connection of the walkway slab to the wall creates positive bending moments in outside face of exterior walls. There is insufficient reinforcement to resist tension resulting in deep cracks (45^0).	Remove rigid connection between walkway slabs and exterior wall.

Table 2.6.1 (4/9) - Scope of Rehabilitation for Civil Works

Facility Name	Structure	Condition Assessment	Recommended rehabilitation
5. Aeration Tank	Tank walls	Exterior walls have insufficient reinforcement to prevent temperature cracks caused by temperature differentials.	Provide new exterior wall 150mm thick. Seal exposed concrete surfaces.
	Tank floors	The floor finish appears to be in good condition. The screed finish is cracked along the movement joint (normal) but is not delaminated. Leakage in floor joints is probable.	Provide new expansion joint and 100 mm concrete floor over existing.
	Aerator slab	Frost damage caused by inadequate surface drainage and spray from aerator. Reinforcing steel is exposed and corroded. The 150mm slab does not have sufficient mass to dampen vibrations.	Remove existing slab and beams and reconstruct to larger dimensions. Coat underside of slab with epoxy resin finish.
		Inadequate floor pad for support of surface aerator.	Provide concrete base with vibration isolating pads.
	Aerator columns	Inadequate concrete cover over reinforcement	Remove loose concrete and expose reinforcing steel. Remove rust and coat with rust inhibitor. Reform columns with additional 100mm concrete cover on all sides
		frost damage at water line.	Repair and coat with epoxy resin
	Outlet Structure	Access to sluice gates is difficult especially during winter. Steel ladders are corroded	Provide open grate catwalk and railings
		wooden stop boards are rotted	Provide new (3)
		Leakage was observed at horizontal construction joints.	Seal all construction joints.
6. Final Sedimentation tanks	General	Steel ladders, walkways and railings are rusted.	Remove corrosion and coat with rust inhibitor. Finish with weather resistant paint.
	Inlet structure	Inlet sluice gates located at aeration tank are leaking.	Replace packing and grease spindle
	Tank walls	The hydraulic leakage test confirmed that leakage through cracks and expansion joints is excessive. Several of the cracks that were previously repaired are leaking.	Seal all cracks and construction joints. Repair expansion joints.

Table 2.6.1 (5/9) - Scope of Rehabilitation for Civil Works

Facility Name	Structure	Condition Assessment	Recommended rehabilitation
6. Final Sedimentation tanks	Tank walls	Inside walls of tank have inadequate cover over reinforcement. Steel is corroded and exposed over most of the surface area.	Expose and treat all corroded reinforcing steel. Provide new concrete wall 150mm thick on inside face to increase cover and facilitate repair of expansion joints. Provide protective coating for high and low water levels.
	Tank floors	The floor finish appears to be in good condition. The screed finish is cracked along the movement joint (normal) but is not delaminated. Leakage in floor joints is probable.	Remove existing screed mortar. Provide new expansion joint and 100 mm concrete floor over existing.
	Overflow Channel	Leakage was observed at all vertical & horizontal expansion joints and several deep cracks	Seal all cracks and construction joints. Repair expansion joints.
7. Flow metering	Parshall flume	No civil structural repairs or modifications	
8. Recycle sludge pumping station	General	Concrete stairs leading up to pump station control room are badly damaged by weathering. Reinforcing steel is exposed and corroded. Hand rails are corroded.	Remove concrete stairs and replace with open grate steel stairs, landings and railings.
		Insufficient surface area at outlet channel for operation and maintenance.	Cover intake structure wells with open steel grating
		The wood stop boards used for isolating flow of recycled sludge to the aeration basin are rotted.	Provide new stop boards
	Walls & floor of recirculation channel	Leakage was observed at horizontal construction joints between wall and floors	Seal all cracks and construction joints. Repair expansion joints.
9. Primary sludge pumping station	General	Inadequate operating space around valve operators and no access to wet well for maintenance.	Provide open steel grating platform over wet well with aluminum access ladder into wet well..
	Pump room	Pumping room is prone to flooding because the floor elevation is lower than ground level.	Remove door and seal opening. Provide new access stairwell to below grade entrance. Water proof exterior of structure and backfill around pump station and sedimentation tanks.
	Wet well	Wet well structure is in good condition but is showing signs of aging (many small cracks)	Provide waterproof coating on the exterior of the wet well and provide a liner on the interior to improve liquid retention.

Table 2.6.1 (6/9) - Scope of Rehabilitation for Civil Works

Facility Name	Structure	Condition Assessment	Recommended rehabilitation
10. Sludge Thickener	General	Access via the roof of the pumping station is difficult in the winter. Steel ladders, walkways and railings are rusted.	Provide open grate steel stairs along side of one sludge thickener. Remove rust on existing walkways and railings and coat with protective paint.
	Tank walls	The tanks were not tested hydraulically. Visual inspection revealed many deep cracks in the walls on overflow launder. Leakage through cracks and expansion joints appears to have been a problem in the past and several of the cracks were previously repaired.	Seal all cracks and construction joints. Repair expansion joints.
		Inside walls of tank have inadequate cover over reinforcement. Steel is corroded and exposed over most of the surface area.	Expose and treat all corroded reinforcing steel. Provide new concrete wall 150mm thick on inside face to increase cover and facilitate repair of expansion joints. Provide protective coating at high and low water levels.
	Tank floors	The floor finish appears to be in good condition. Crack opening along bottom movement joints is less than 5 mm and there is no evidence of leakage through the joint. The bottom screed is cracked along the movement joint (normal) but is not delaminated.	No action required
11. Thickened Sludge pumping Station	General	There is no access to the wet well for maintenance	Cover top of wet well with open grating. Provide aluminum access ladder into wet well.
	Wet well	There is visible evidence of past leakage in the walls of the wet well.	Provide a waterproof liner on the inside of the wet well
12. Sludge Digester	General	Steel access ladders and platforms are damaged and corroded	Replace with new platforms and handrails.
		The digesters are approximately 2/3 full of sludge which has been dormant since April 1992.	Remove liquids and solids. Clean digesters.
	Thermal Insulation	Insulation on walls and roof is damaged.	Remove existing insulation and replace with 400mm rigid polystyrene covered with protective metal cladding.

Table 2.6.1 (7/9) - Scope of Rehabilitation for Civil Works

Facility Name	Structure	Condition Assessment	Recommended rehabilitation
12. Sludge Digester	Concrete	The digesters are approximately 2/3 full of liquid sludge. There is no apparent leakage. Some small surface areas have been damaged by projectiles but there is no structural damage.	Patch all damaged areas with epoxy mortar. Perform hydraulic test with insulation removed to ascertain water tightness. Repair leaks with epoxy injection if necessary.
	Anti-corrosion protection	Contact with bio-gas can lead to considerable deterioration of the concrete on internal walls and dome. A protective coating was applied during construction however a visual inspection to ascertain conditions inside the digester was not possible.	Inspect dome and side-walls between high and low sludge levels. Replace coating if required.
	Valves	The gate valves at the base of the digester have been damaged by freezing. The valve casings have split and sludge is leaking out onto the ground.	Replace all valves and provide heat tracing to prevent freezing
13. Boiler House	Building	Existing building will be reconstructed	No action required
14. Gas Compressor Station	Building	Existing building will be reconstructed	No action required
15. Gas Storage Tank	Concrete	The tank is usually filled with water to provide a seal between the roof and the wall of the tank. Visual inspection of the tank walls reveals many cracks and construction joints with visible signs of previous leakage. Hydraulic test indicates that leakage is small.	Seal all cracks and joints with epoxy injection from the inside. Provide epoxy resin coating to inside surface.
	Roof	The gas holding tank is fitted with a floating steel roof. The roof appears to be in good condition but needs anti-corrosion coating on both sides	Temporarily raise roof and support on scaffolding. Sandblast corrosion and old finish. Apply epoxy paint to all exterior steel surfaces. Apply epoxy tar coating on interior surfaces to protect from gas corrosion.

Table 2.6.1 (8/9) - Scope of Rehabilitation for Civil Works

Facility Name	Structure	Condition Assessment	Recommended rehabilitation
16. Homogenized Sludge Holding Tank	General	Steel ladders, walkways and railings are rusted.	Provide open grate steel stairs along side of one sludge thickener. Remove rust on existing walkways and railings and coat with protective paint.
	Tank walls	The tanks were not tested hydraulically. Visual inspection revealed many deep cracks in the walls. Leakage through cracks and expansion joints appears to have been a problem in the past and several of the cracks were previously repaired.	Seal all cracks and construction joints. Repair expansion joints.
		Inside walls of tank have inadequate cover over reinforcement. Steel is corroded and exposed over most of the surface area.	Expose and treat all corroded reinforcing steel. Provide new concrete wall 150mm thick on inside face to increase cover and facilitate repair of expansion joints. Provide protective coating at high and low water levels.
	Tank floors	The floor finish appears to be in good condition. Crack opening along bottom movement joints is less than 5 mm and there is no evidence of leakage through the joint. The bottom screed is cracked along the movement joint (normal) but is not delaminated.	No action required
17. Sludge pumping station	General	There is no access to the wet well for maintenance	Cover the wet well with a steel grating and provide an aluminum access ladder into the wet well.
	Walls & floor of recirculation channel	Walls appear to be liquid tight however the structure was not hydraulically tested.	No action required

Table 2.6.1 (9/9) - Scope of Rehabilitation for Civil Works

Facility Name	Structure	Condition Assessment	Recommended rehabilitation
18. Sludge Dehydration	No civil structural repairs or modifications		
19. Air blower room	No civil structural repairs or modifications		
20. Power station	No civil structural repairs or modifications		
21. Sub-station	No civil structural repairs or modifications		
22. Reception	No civil structural repairs or modifications		
23. Admin.	No civil structural repairs or modifications		
24. Service Water Pumping Station	No civil structural repairs or modifications		
25. Main laboratory	No civil structural repairs or modifications		

CHAPTER 3. ARCHITECTURAL WORK

Basically, the goal for rehabilitation of the WWTP facilities is to bring it back to the pre-war condition. Although it does not require large-scale rehabilitation for the next 10 years, it is necessary that the building facilities require regular maintenance work.

3.1 SUPER STRUCTURE

Since the field tests showed that the actual strength of the structures has the intensity of what is required, rehabilitation is not necessary. Repair work will be required on some broken portions that are evident.

3.2 FITTINGS

Severe corrosion and damages had occurred to the fittings and need new replacement. Apparently, replacement to some of the buildings had already been done by direct management of the ViK.

3.3 WATERPROOFING

Traces of water leakage can be seen in most of the buildings. On the other hand, the waterproofing materials had deteriorated and weakened after they lapsed the general durability year of 10. Thus a general replacement will be necessary.

3.4 EXTERIOR AND INTERIOR FINISH

Repair of the mortar finish is required where broken portion is visible. Complete exterior finishing work is necessary. Complete repair and finishing works are required since exfoliation and stains on the walls are severe.

3.5 LIGHTING EQUIPMENT

Most of the buildings had missing lighting equipment, while those that are existing are severely corroded and damage. Therefore, general replacement of lighting equipment is necessary.

3.6 HEATING AND VENTILATION EQUIPMENT

Heating equipment including piping is necessary. Most of the buildings had missing ventilation equipment, while those that are existing are severely corroded and damage. General replacement of ventilation equipment is essential.

3.7 SANITARY AND FIRE EQUIPMENT

All buildings must be equipped with sanitation facilities. Replacement of the fire extinguishers is imperative since the existing equipment is severely corroded. Appropriate type of fire extinguishers especially for fire caused by oil and electricity are required in boiler & engine generator room, power house and pumping stations.

3.8 FLOOD CONTROL MEASURE

Flooding can cause fatal damage to plant machinery and electrical equipment that may lead to facility breakdown. In most of the buildings, there are traces of flooding on the inside walls. To avoid damage due to flooding, appropriate flood control measures are essential to include raising up of the floor level with the equipment base above the maximum flood line, and construction of waterproof embankment.

CHAPTER 4. MECHANICAL WORK

Inspection work for mechanical equipment was carried out from the beginning of June to middle of July 1999 at the Sarajevo Wastewater Treatment Plant. The results of the inspection are explained below with the Inspection Sheets with Photo-documentation compiled in **Appendix I**.

4.0 MAIN INLET GATE

The drive motor for the gate is removed and part of reducer is broken, only the hand lever exists and the gate is operable manually. Two lifting spindles are slightly deformed and closing the gate thoroughly is difficult. Level indicator of the gate is not complete. Picture 0-M 1 **Appendix I** show the inside structure of the level indicator. Picture 0- M 2 shows that the level indicator for the gate being fully closed. Picture 0- M 3 shows the gate only with hand lever. Picture 0- M 4 shows the whole view of the gate.

As a conclusion, the Main Inlet Gate needs to be replaced with new one including auxiliaries.

4.1 RAW WATER PUMPING STATION

4.1.1 Screw Pumps No. 1 to 4

The grease lubrication system for lower bearings of all pumps are damaged or broken. Picture 1- M 1 to 4 show the condition of the grease lubrication system and drive motors. Anti-rust coat of paintings for all four pumps is almost in the same condition and not bad except at the edges of four pumps.

All drive units including reducers and foot bearings need to be replaced with new ones. The screws and shafts could be utilized, but need cleaning, protection of corroded parts, anti-rust painting and readjustment.

4.1.2 Rail Crane for Screw Pumps

The crane is not in good condition. Spare drive motor is dismounted. Cables of command from the ground and switch cabinet are not complete. The crane and auxiliaries need to be replaced with new one.

4.2 SCREENING STATION

4.2.1 Stop Gate with Motor Drive for Screening Station

The stop gate is not in good condition. Complete manufacturer's table with the data is missing. The stop gate and auxiliaries needs to be replaced with new one.

4.2.2 Stop Gate with Manual Drive No. 1 to 3

All 3 stop gates can be operated manually by a much bigger force of 15 kg. Several numbers of bolts and nuts are corroded heavily. The gate plates and structures can be utilized. However, all bolts and nuts as well as retainers sheets need to be replaced with new ones and to be readjusted.

4.2.3 Automatic Coarse Screen No. 1 to 4

The drive motors for all 4 screens are not complete and these facilities are damaged severely. These coarse screens need to be replaced with new ones.

4.2.4 Automatic Fine Screen No. 1 to 4

The drive motors of all 4 automatic screens are not complete and the screens are damaged severely. These fine screens need to be replaced with new ones.

4.2.5 Stop Gate with Motor Drive

The stop gate is not in good condition. Complete manufacture's table is missing. The stop gate and auxiliaries need to be replaced with new one. (Pictures are not available because of too narrow space for taking photo).

4.2.6 Stop Gate with Hand Drive No. 1 to 3

These gates can be operated manually by applying a much bigger force of 15 kg. Several of the bolts and nuts are corroded heavily. However, the gate plates are still usable provided that the bolts and nuts as well as retainers are replaced with new ones.

The remaining gate structures need to be cleaned and applied with anti- rust protection paintings and readjusted. (Pictures are not available because of too narrow space for taking photo).

4.3. AERATED GRIT CHAMBER

4.3.1 Sand Trap Bridge

The metal bridge construction is attacked heavily by corrosion. The bridge drive motor is rusted and the flexible cab tire cable is missing. At the bridge, there are mammoth pumps and pipelines for grit removal but these items had already lapse their usable life.

4.3.2 Aeration System

The aeration system, made of galvanized pipe with nozzles for production of air bubbles is damaged severely.

As a conclusion, the whole aeration and sand trap mechanism and auxiliaries need to be replaced with new one.

4.3.3 Aeration Sand Trap Inlet Gate No. 1 to 3

All of these gates are operable manually, provided a power of about 15 kg is applied. Several of the bolts and nuts are corroded heavily. The gate structures are usable, however all bolts and nuts as well as retainers are to be replaced with new ones. The gate structures need to be cleaned, readjusted and application of anti-rust protection painting is necessary. (Pictures are not available because of too narrow space for taking photo).

4.3.4 Scum Channel Inlet Gate No. 1 to 3

All of these gates can be operated manually by applying a force of about 15 kg. Several of the bolts and nuts are corroded heavily. The gate structures are still usable, however the bolts and nuts as well as retainers are to be replaced with new ones. The gate structures need to be cleaned, readjusted and application of anti-rust protection painting is necessary. (Pictures are not available because of too narrow space for taking photo).

4.3.5 Aeration Sand Trap Outlet Gate No. 1 to 3

All of these of these gates can be operated manually by applying a force of about 15 kg. Several of the bolts and nuts are corroded heavily. The gate structures are still usable provided that the bolts and nuts as well as retainers are replaced with new ones. The gate structures need to be cleaned, readjusted and application of anti-rust protection painting is necessary. (Pictures are not available because of too narrow space for taking photo). A more detailed information for the sluice gates is compiled in **Appendix D**.

4.4 PRIMARY SEDIMENTATION TANK NO. 1 & 2

The drive motors for traction drive heads are dismounted with drive heads both damaged. Some diagonal beams are corroded very severely and the bolts and nuts are rusted. The traction drive heads with drive motors need to be renewed. The corroded diagonal beams need to be replaced with new one with all bolts and nuts need replaced with stainless steel. The rake's blade needs to be newly replaced.

4.5 AERATION TANK

There are 36 sets of 37 kW aeration turbines existing. Among them 3 sets of turbines are without drive motors. Two sets are not properly installed (with considerable inclination). Two sets of oil piping for reducers are broken and 10 sets of coupling between drive motors and reducers are damaged.

Nineteen (19) sets of aerator turbines were selected for 2 hours continuous load testing. The test was carried out from 19 June to 5 July 1999. The results show that 19 out of 33 aeration turbines can be used. A more detailed information for the surface aerator load testing and sluice gate inspection are compiled in **Appendix C and D**, respectively.

4.6 FINAL SEDIMENTATION TANK NO. 1 TO 4

The drive motors of 4 tanks are dismounted with 4 drive heads incomplete. The structure's mechanism is partly attacked by rust and almost all bolts and nuts are corroded heavily. The structure's mechanism can still be used provided that cleaning, protection of corroded part, and application of anti rust protection painting are done. The central sliding sleeves need to be replaced with new ones. All the bolts and nuts need to be replaced with stainless steel.

4.7 FLOW METERING

Nothing is existing. The flow meter is weir type with water level meter and transducer. The entire metering equipment including auxiliaries are to be newly installed.

4.8 RECYCLED SLUDGE PUMPING STATION

4.8.1 Screw Pump No. 1 & 2

The grease lubrication system for lower bearings of the two pumps are damaged or broken. Painting for screws and shafts are not in bad condition. The drive units including reducers and lower foot bearings need to be replaced with new ones. The screws and shafts are usable, however cleaning, protection of corroded parts, anti rust painting and readjustment are necessary.

4.9 PRIMARY SLUDGE PUMPING STATION

4.9.1 Torque Flow Type Pump No. 1 to 2

These pumps are damaged severely and no drive motors exist. These pumps appear to have lapsed their usable lives. Therefore, replacement including auxiliaries is necessary.

4.10 SLUDGE THICKENER WITH PICKET NO. 1 & 2

The drive motors of the sludge thickeners are missing with drive heads incomplete. The structure's mechanism is partly attacked by rust and certain numbers of bolts and nuts are corroded heavily. The structure's mechanism can be used, however cleaning, protection painting of corroded parts and readjustment are necessary. All bolts and nuts need to be replaced with stainless steel. The drive units need to be replaced with new ones.

4.11 THICKENED SLUDGE PUMPING STATION

4.11.1 Torque Flow Type Pump No. 1 & 2

These pumps are damaged severely and no drive motors exist. The pumps appeared to have lapse their useful life. Therefore, the pumps including auxiliaries and drive motors need to be replaced with new ones.

4.12 SLUDGE DIGESTERS

4.12.1 Torque Flow Type Pump No. 1 to 3

These pumps are damaged very severely and seem to have lapse their useful life. Therefore, all pumps and auxiliaries as well as drive motors are to be replaced with new ones.

4.13 BOILER HOUSE

4.13.1 Sludge Heat Exchangers

The double tube heat exchangers come in contact with sludge and water inside and outside for heat exchange. However, these heat exchangers seem to have lapse their useful life. Therefore, all heat exchangers including auxiliaries need to be replaced with new ones.

4.14 GAS COMPRESSOR STATION

4.14.1 Digested Gas Compressor No. 1 to 6

Digested gas is recirculated for sludge mixing and three compressors of 37 kW capacity each are used for the purpose. The digested gas from gas storage tank is transported to power generation station and another 3 compressors of 30 kW capacity each are used. These 6 gas compressors are damaged very seriously. Because of the complexity of these compressors transporting the very explosive gas, replacement is necessary.

4.15 GAS STORAGE TANK

The gas storage tank has a floating roof type, with cove of steel, welded with anti corrosive protection, and installed on the concrete ground pool. Gas sealing is done by water. The gas tank is provided with necessary servicing pipes and reinforcement for pressure keeping. The floating roof including supporting guide mechanism need to be applied with anti- rust protection painting, repair of guide support mechanism is necessary to strengthen the anti frozen measure of sealing water during winter time. The necessary auxiliaries need to be newly replaced.

4.16 HOMOGENIZED SLUDGE HOLDING TANK

The drive motor is dismounted and drive head is incomplete. The structure's mechanism is partly attacked by rust and most of the bolts and nuts are corroded heavily. The driving mechanism is usable but require cleaning, and application of anti rust protection painting. All bolts and nuts are to be replaced with stainless steel. The drive head needs to be replaced with new one.

4.17 SLUDGE PUMPING STATION

4.17.1 Moineau Pump No. 1 to 5

The pumps have the eccentric rotors driven by electrical motor through a reducer, so that the numbers of turns can be regulated. All the drive motors, a part of transmission mechanism and reducers are dismounted. Almost all parts except for pump casings are not existing. Therefore, all the pumps need to be replaced with new ones.

4.18 SLUDGE DEHYDRATION

4.18.1 Belt Filter Press No. 1 to 5

All 5 belt filter presses are devastated. The electrical motors and transmission mechanisms, part of automatics, filter clothes are dismounted. The piping system of the air automatics is cut. Therefore, all the 5 filter presses need to be replaced with new ones.

4.19 AIR BLOWER ROOM

4.19.1 Air Blower for Aerated Grit Chamber No. 1 to 3

There are no motors existing. Part of the flexible coupling that is placed on the motor is also missing. The blowers are damaged severely. Therefore, all the blowers need to be replaced with new ones including auxiliaries.

4.20 POWER STATION

4.20.1 Diesel Engine for Power Generation

These diesel engines were manufactured 19 years ago in 1980. Since that period the operation of these engines were short due to the following:

(a) it was the commissioning period in 1984
(b) suffered many operational interruption due to lack of gas production
(c) the whole plant stopped operation in April 1992 due to the war

Due to the long standstill condition and disaster in April 1992, replacement of these machines with new units is safer and more cost effective than refurbishment.

4.21 SERVICE WATER PUMPING STATION

There are 4 pumps with 2 of 37 kW motors and another 2 of 30 kW. The bigger pumps are with motors but the smaller pumps are without. These 4 pumps are damaged very severely including its accessories. Therefore, all 4 pumps and auxiliaries need to be newly replaced. The small pumps need new motors while the bigger pumps' motors can be used with small repairs, such as replacement of bearings and rewinding.

CHAPTER 5. ELECTRICAL WORK

5.1 OUTLINE OF ASSESSMENT WORKS

For electric facilities, it was confirmed from the First Field Survey that most of the electrical equipment were removed and taken away. Therefore, during the Second Field Survey reconfirmation was done on what equipment are existing or missing. A detailed inspection and assessment were performed with Inspection Sheet for every equipment installed in each facility.

For motors of aeration turbine, on-load test for each motor was performed with mechanical load under normal water condition in the Aeration Tank. The on-load test was performed by USB Kedly Doo, Sarajevo.

5.2 METHOD OF INSPECTION

The inspection and assessment of electrical facilities and equipment were performed and are explained in detail in **Appendix J** (Inspection Sheets – Electrical Aspects). The Result of inspection is classified as follows:

<table>
<tr><td rowspan="4">Result of Inspection</td><td>Class</td><td>Condition</td></tr>
<tr><td>○</td><td>• There is no physical damage
• Function is normal and accurate.
• There is no problem.</td></tr>
<tr><td>△</td><td>• Physical problem is existing or progressing. (Figure, corrosion, insulation resistance, and others).
• Some of the functions are out of order.</td></tr>
<tr><td>×</td><td>• There is a big damage on the physical characteristics or function.</td></tr>
</table>

The above result of inspection is assessed in the table below.

<table>
<tr><td rowspan="4">Recommendation</td><td>Class</td><td>Assessment</td></tr>
<tr><td>A</td><td>Entire equipment shall be newly replaced.</td></tr>
<tr><td>B</td><td>The equipment can be repaired.
Some parts can be replaced or supplied.</td></tr>
<tr><td>C</td><td>The equipment can be used without repair.</td></tr>
</table>

5.3 SUMMARY OF INSPECTION AND ASSESSMENT

5.3.1 Electric Power Supply System

(1) Power Station (Facility 20)

In this power station, 2 units of 640 kW (800 kVA), 400V, 50Hz synchronous generator coupled with diesel engine exists. The exciters of both generators were destroyed. Therefore, new replacement will be necessary.

The generator control panels are seriously damaged. The metal enclosed panels are broken. Almost all electrical instruments/parts are missing. All inside wiring of panel are cut.

The high-tension (HT) switch gears and low tension (LT) power distribution/motor control panels are heavily damaged as much as the generator control panels.

The 2 units transformers of 10/0.4 kV, 1000 kVA and 2 units transformers of 10/0.4 kV, 1600 kVA were removed and taken away.

All HT and LT cables were cut and were taken away.

It is considered that all electric equipment and cables shall be newly replaced or reconstructed.

(2) Substation (Facility 21)

In this substation, the HT switchgear and LT power distribution/motor control panels are heavily damaged. The metal enclosed panels are broken, and stain & corrosion are progressing on the panels. Almost all electrical instruments/parts were removed and taken away. All inside wiring of panels are cut and taken away.

The 1 unit transformer of 10/0.4 kV, 1600 kVA is missing.

All HT and LT cables were cut and were taken away.

It is considered that all electric equipment and cables shall be newly replaced or reconstructed.

5.3.2 Electric Motor

Currently, the following electric motors are existing under non-operating condition.

(1) Motor for Aeration Turbine (37 kW, 4 P, 380 V × 33 units)
(2) Motor for Raw Water Pump (160 kW, 4 P, 380 V × 4 units)
(3) Motor for Recycled Sludge Pump (100 kW, 4 P, 380 V × 2 units)
(4) Motor for Service Water Pump (37 kW, 2 P, 380 V × 2 units)
(5) Motor for Gas Compressor (37 kW, 6 P, 380 V × 3 units)

(30 kW, 4 P, 380 V × 3 units)

All the rest of the motors not mentioned above are missing.

(1) Inspection and Test Performed

a.) Motor for Aeration Turbine

Out of the total 36 aerators, the motors for 33 aerators exist but 3 are missing. Physical inspection such as body assessment degree of stain/corrosion, coil conductivity check, and insulation resistance measurement were performed.

Out of the 33 aerators with motors, 19 of them passed the criteria (mechanical and electrical soundness and structural stability) for testing. On load test was performed for each motor under normal water level condition in the Aeration Tank.

b.) Other Motors

Physical inspection was performed on these motors to include body assessment, degree of corrosion/stain, coil conductivity check, and insulation resistance measurement.

For these motors, the mechanical load facilities exist but not arranged. Therefore, on load test can not be performed.

(2) Assessment

Accordingly, the inspection and test result of these motors showed that they could still be used. However, since they had not been operated for 7 years starting 1992, overhaul including change of bearing is necessary to attain a long operational life.

Aside from the above-mentioned problems, rust and corrosion are heavily progressing inside of the terminal box. The terminal bolt for the motors of the Gas Compressor is severely corroded. The insulation resistance of these motors is reduced. Therefore, long operation life for these motors can not be expected.

It is recommended that these motors should be newly replaced.

5.3.3 Control Facilities

(1) Central Control Panel

The central control panel is installed in the Administration Building (Facility 23). It is consist of the main control panel and operator console. These panels are heavily damaged. Although the metal enclosed panel is existing, the electrical instruments/parts inside are missing. Therefore no function can be carried out in the central control panel.

It is considered that these panels should be newly replaced.

(2) Local Control Panels

The Local Control Panels are installed at the following locations.

a) Raw Water Pumping Station (Facility 1)
b) Power Station (Facility 20)
c) Recycled Sludge Pumping Station (Facility 8)
d) Primary Sludge Pumping Station (Facility 9)
e) Thickened Sludge Pumping Station (Facility 11)
f) Boiler House (Facility 13)
g) Sludge Dehydration (Facility 18)
h) Compressor Station II (Facility 19)
i) Service Water Pumping Station (Facility 24)

All of these panels are severely damaged in the same manner as the central control panel.

It is recommended that these panels should be newly replaced.

(3) Measuring Equipment

Measuring equipment were installed previously in the Flow Metering (Facility 7), Aeration Tank (Facility 5), and others.

a) Flow metering
There is no instrument.
The instrument were removed and taken away.

b) Aeration tank
There are Dissolved Oxygen meters (4pcs).
But they are all broken.

c) Others
Instruments were removed and taken away, or broken.

It is considered that all measuring instruments shall be newly replaced or reconstructed.

5.3.4 Cabling

All HT & LT cables and measuring/control were cut and taken away.

Therefore it is recommended that these cables and measuring/control devices shall be newly replaced and reconstructed.