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United Nations Industrial Development Organisation (UNIDO)

KASUR TANNERIES POLLUTION CONTROL PROJECT - DP/PAK/93/006

Assessment of Drainage System Civil Works

Final Report

July 1997

HALCROW

United Nations Industrial Development Organisation (UNIDO)

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United Nations Industrial Development Organisation (UNIDO)

KASUR TANNERIES POLLUTION CONTROL PROJECT - DP/PAK/93/006

Assessment of Drainage System Civil Works

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EXECUTIVE SUMMARY

This report contains an evaluation of the civil works for the partially completed drainage system for the Kasur Tanneries Pollution Control Project, in Kasur, Pakistan. The report has been prepared by Halcrow Pakistan (Pvt) Ltd (HP) for the United Nations Industrial Development Organisation (UNIDO) under contract 97/009 (PO No 15-7-1009X).

The primary objectives of this study were to confirm the hydraulic grades of the drainage system and the use of sulphate resisting cement as well as to review the long-term durability of the drainage system under actual conditions of operation.

A large portion of the drainage system has been completed. Construction work for the post-treatment drainage system was undertaken by five contractors. Pipes were manufactured on-site, however one contractor used pipes which were manufactured off-site.

Field work was carried out between 5 and 13 May 1997. Various activities including survey of drainage system, testing and visual inspection of concrete, limited monitoring of effluent quality and measurements of hydrogen sulphide gas concentrations were undertaken during the field work. In addition to this, samples of concrete and plaster were obtained for laboratory testing. The samples were tested for a number of parameters in three different laboratories. Both the field testing results and the laboratory results were used in assessing the quality of work.

An evaluation of the drainage works, confirming the hydraulic grades of the drainage system and the quality of the completed civil works including the durability of the pipeline and open channel structures, has been carried out. In addition to this a number of other relevant observations made during the field work, are also reported.

The overall slope of the open channel and the pipeline is steeper than design however there are significant deviations from a uniform profile, indicating poor survey control during construction. There are constrictions in the open channel cross section and unless they are removed, the flow conditions will significantly affect the channel hydraulics.

The pipeline concrete generally appears to be of good quality and free of visible construction defects. Similarly the overall quality of workmanship in the construction of the open channel appears to be satisfactory. However manhole covers were generally found to be of much poorer construction than the pipeline.

Approximately, 70 percent of the pipeline is reported to have been constructed using Ordinary Portland Cement (OPC). The remaining 30 percent is constructed using Sulphate Resisting Cement (SRC). Similarly plaster used in the construction of the channel is reported to contain SRC over 94 percent of the length of the channel with OPC plaster over the remainder. Laboratory tests have confirmed that cement types were used as reported.

Sulphate attack on the pipeline concrete is unlikely to be a significant issue, however for the future, this needs to be supported by direct testing of the wastewater. There is ample evidence that acid attack due to the build-up of hydrogen sulphide and subsequent formation of sulphuric acid is currently taking place in the pipeline. There has also been serious degradation of a number of manhole covers due to this process, and this has occurred within about six months of the pipe being put into operation.

It is anticipated that the asphaltic lining applied on the walls of the open channel will deteriorate rapidly unless it is routinely maintained and periodically replaced. If, subsequently, the wastewater does enter the brick work it may lead to spalling of the channel walls. However it should not seriously impair the structural integrity of the channel.

There is no detailed design information available for the drainage system, other than a feasibility study prepared in 1992. A feasibility level design is not usually adequate for the implementation of a project of this magnitude.

The change made in the use of cement type at a late stage of construction means that 70 percent of the as-built pipeline and 6 percent of the open channel do not conform with the final design basis adopted by Kasur Tanneries Waste Management Agency (KTWMA).

Lean concrete fill has been used as bedding for the pipeline. This is considered unduly conservative and uneconomical for the conditions prevailing in Kasur.

There is a need to provide ventilation of the pipeline to vent potentially dangerous and corrosive gases. In order to assess the aggressiveness of the effluent, the quality of effluent should be monitored

A number of construction quality control practices and key routine tests appear not to have been carried out. Reported methods of on-site construction monitoring, testing and record keeping were inadequate for a project of this magnitude.

1 INTRODUCTION

This report contains an evaluation of the civil works for the partially completed drainage system for the Kasur Tanneries Pollution Control Project, in Kasur, Pakistan. The report has been prepared by Halcrow Pakistan (Pvt) Ltd (HP) for the United Nations Industrial Development Organisation (UNIDO) under contract 97/009 (PO No 15-7-1009X).

A proposal was prepared by HP in response to a verbal request from UNIDO Islamabad for carrying out an evaluation of the quality of the concrete works on 25 November 1996. It was subsequently modified on 26 November to include a survey of the drainage system and resubmitted to UNIDO. At this time it was established that the system comprises approximately 5.9 km of pipeline and 1.6 km of open channel. The proposal was again submitted on 10 March 1997 together with a detailed programme. These proposals outline the scope of work for the project and form the basis of the contract between UNIDO and HP.

The scope of work was broken down into a preliminary evaluation, a detailed evaluation and a survey. Field work was completed between 5 to 13 May 1997 and laboratory testing between 13 May and 20 June 1997. An interim status report was submitted on 26 May.

2 PROJECT DESCRIPTION

The city of Kasur is situated 55 km southeast of Lahore. The Kasur Tanneries Pollution Control (KTPC) Project is part of the Kasur Environment Improvement Programme (KEIP). The project is jointly funded by the Government of Pakistan, Government of Punjab, Tanneries Association Dingarth (TAD) and United Nations Development Programme (UNDP). Technical assistance for the project is provided by the United Nations Industrial Development Organisation (UNIDO), and it is being implemented through the Kasur Tannery Waste Management Agency (KTWMA) of the Kasur Development Authority (KDA), Government of Punjab.

Implementation of KTPC is planned in phases. Phase 1 has the following objectives.

- Introduction of better process control in tanneries;
- In-house pretreatment in tanneries;
- Establishment of the overall drainage system including evacuation of the existing stagnant pools.

2.1 Disposal of Tannery Effluent

There are 159 tannery units in the eastern part of the Kasur city. These are divided into the following four tannery clusters.

1.	Dingarh	46 Tannery Units
2.	Kot Abdul Qadir	33 Tannery Units
3.	Younus Nagar	64 Tannery Units
4.	Niaz Nagar	16 Tannery Units

Effluent from these tanneries is discharged to the low-lying area on the east of Niaz Nagar as well as into the Rohi Nallah flowing on the western side of Dingarh (Drawing PKKTCE01). Flow in the Rohi Nallah consists primarily of domestic sewage from the city of Kasur and tannery effluent from Dingarh. The Nallah is finally discharged into the Pandoki Drain approximately 7 km South-West of Kasur. Discharge of tannery effluent to the low-lying area has resulted in three large pools of stagnant effluent east of the tannery clusters. It is estimated that these pools cover an area of 500,000 square metres with a total volume of 300,000 cubic metres of untreated tannery effluent.

2.2 The Overall Drainage System

The overall drainage system designed for the collection and disposal of effluent from all 159 tannery units consists of the following components.

Dingarh Collector
Dingarh Pump Station
Pressure Pipeline
Pucca Drain

Younus Nagar Drainage
Younus Nagar Pump Station
Final Outfall

The system can be broadly classified into two parts. The first part consists of a collection and pumping system which will convey effluent to the Common Effluent Pre-Treatment Plant (CEPTP). The second part will carry the treated effluent from the CEPTP final discharge in the Pandoki Drain.

Effluent from tannery units will be collected by a network of small size brick/cement mortar open channels covered with removable concrete slabs. Collected effluent from each individual cluster will be transferred to the Pucca drain which will carry it to the CEPTP.

Effluent from Kot Abdul Qadir and Niaz Nagar will flow to the Pucca drain under gravity whereas effluent from Dingarth and Younus Nagar will be collected at two different pumping stations from where it will be pumped into the Pucca drain. A peripheral channel will collect stormwater from the area east of Niaz Nagar and will discharge it directly into the post-treatment drainage channel.

The post-treatment drainage system channel is constructed parallel to the Kasur-Dipalpur road. This drainage channel will receive the treated effluent from CEPTP and will discharge it into the Pandoki drain. The initial section of about 1.66 km is constructed as a rectangular open channel with a width of 3 metres and depth varying between 1.2 to 1.8 metres. The walls of the open channel are constructed with brick/masonry faced with plaster. The bed of the channel is comprised of a 20 cm brick floor on top of a 15 cm thick 1:4:8 concrete slab. The walls of the open channel are coated with a layer of asphalt or bitumen.

The open channel ends at the Rohi Nallah where it first crosses the Kasur Dipalpur road. This is followed by a 5.9 km long, 1370mm diameter concrete pipe-line which finally discharges into the Pandoki Drain (Photograph 1). The concrete pipeline crosses the Rohi Nallah at two locations. Each location of Nallah crossing comprises of a brick masonry box structures on each bank of the nallah, connected by three 910mm concrete pipes (Photograph 2). These smaller size pipes act as an inverted syphon across the nallah and the box structures provide a transition between the larger and the 3 smaller pipes. In order to minimise inflow of stormwater into the pipe-line, the top of the box structure walls are approximately equal to the level of adjacent road and above the level of the surrounding ground. A total of sixty manholes are provided on the concrete pipe line at spacings of approximately 100 metres.

Following the construction of above channel spacings and pipeline, the flow in the Rohi Nallah has been diverted into the concrete pipe line. Previously, the Rohi Nallah used to flow through agricultural land before discharging to the Pandoki Drain. By diverting it into the pipeline, this land has been drained. The pipe line now discharges the effluent into the Pandoki drain approximately 2.25 km downstream of the original outfall of the Rohi Nallah (Drawing PKKTCE01). The Pandoki drain has been constructed as a part of Salinity Control & Reclamation Programme (SCARP) and ultimately discharges into the Sutlej river.

2.3 Construction of Drainage System

Construction of post treatment drainage system started in December 1995. Although a large portion of the drainage system has now been completed, there are a few sections where the work has not been finished. Construction of the post-treatment drainage system was undertaken by five contractors. Table 3.6 gives the length of sections constructed by each contractor.

It is reported that pipes were manufactured at three casting yards on-site, however one contractor purchased precast pipes from Lahore.

Concrete with a mix design of 1:1.5:3 and water cement ratio of 0.4 to 0.45 was used in manufacturing pipes. The normal practice of pipe manufacturing was to arrange circular reinforcement so as to form two cages of different diameters. In each cage, circular reinforcement was supported by longitudinal reinforcement designed for temperature and shrinkage stresses. In order to ensure a uniform spacing between the two cages, both the cages were welded prior to concrete pouring. Each complete reinforcement cage was weighed to ensure that sufficient reinforcement was used. This was followed by fixing the cage in a formwork capable of spinning at a certain rate. The shape of concrete pipe was achieved by pouring concrete into the spinning formwork. It was reported that approximately 12.5 bags of cement were used to manufacture a typical 8 feet long pipe. This corresponds to a cement content of 385 kg/m^3. At the end of pipe manufacturing, two bags of dry cement powder was applied manually on the surface on concrete so as to soak the surface water. Forms were struck after 24 hours and was followed by a period of curing during which water was sprayed on the surface of concrete pipes curing lasted for 7 to 28 day.

During the manufacturing of concrete pipes 6 inch cube samples were formed from fresh concrete 2 to 3 times per week. The cubes were tested for compressive strength. It is reported that for every contractor two concrete pipes were also tested for three edge bearing tests. The results of these latter tests are given in appendix A. Compressive strength test results were not avaliable to the consultants.

Laying of concrete pipe was carried out after placing lean concrete with a mix design of 1:4:8. The finished surface gave the bed level required for the concrete pipe. After laying the pipes on the bedding surface, they were joined by first sliding a rubber O-ring gasket on one of the pipe end and then joining it with the other pipe end. In this way a typical opposing shoulder joint was achieved. Lean concrete was then poured up to the half of pipe diameter. However, it was reported that this practice was not followed for the entire length of concrete pipe line, and for some of sections lean concrete was poured up to one quarter of the pipe diameter whereas for some other sections lean concrete was only placed upto the bottom of the pipe. No information on the length of these sections was available.

An important concern during the construction was the type of cement type to be used in manufacturing concrete pipes and in constructing the open channel. It is reported that initially Ordinary Portland Cement was used in all types of construction. Later the contractors were asked to use Sulphate Resisting Cement in all types of construction. Subsequently use of slag cement was recommended and, after its use for eight days, contractors were asked to switch back to sulphate resisting cement. Based on the site engineers record, Figure 2.1 presents the length of sections constructed with various cement types. However no record was maintained on the use of slag cement.

3 FIELD INVESTIGATIONS

Assessment of drainage works started with a site visit on 10 April 1997. A team of two members from Halcrow Pakistan, consisting of Chief Engineer Yaver Ali Abidi and Environmental Engineer Naveed Ahmed, visited the site to undertake the phase 1 programme. During an opening meeting with the Managing Director KTWMA, the team was informed that arrangements for the site visit had not been made and, therefore, the phase 1 programme could not be initiated until the finalisation of such arrangements. Therefore the work could not be carried out at the time and the field team was demobilised.

The actual field work was carried out by a three member team from Halcrow Pakistan between 5 and 13 May. The field work started with an opening meeting with Nadeem Ashraf, Assistant National Project Director UNIDO and Abdul Sattar Lillah, Executive Engineer, Government of Punjab/KTWMA. In order to facilitate the proposed field work, the detailed programme of site activities was discussed and information about the project was recorded. During this meeting the team was informed that dewatering of the pipeline was not undertaken as this would damage crops on adjacent land, reclaimed as a result of diversion of wastewater from the Rohi Nallah into the pipeline. This prevented access into and inspection of the pipeline from inside. No direct assessment could be made of the nature of any chemical attack to the pipe surface. In order to fulfill the objectives of this study, a change was made in the programme and it was agreed that the pipe would be inspected from outside at 100 metres intervals. This required hiring local labour to excavate the crown of buried pipe to allow inspection and testing of its external surface.

The description of various activities carried out during the site visit is summarised in the following sections.

3.1 Survey of the Drainage System

A reference point (Halcrow BM) was selected at the start of 54" diameter concrete pipe section. This point was subsequently used as a bench mark for all measurements and manhole numbering.

The total length of both the open channel and the concrete pipeline was measured with a 100 metres fiberglass measuring tape. During measurement of the open channel, points were established on the wall of the open channel at approximately 100 metres interval. However for the concrete pipe section, the actual distance between manholes was measured. These measurements are presented in Tables 3.1 and 3.2.

The invert levels of the open channel and the concrete pipeline were determined at suitable points using an automatic level and staff. For the open channel section levels were recorded at the pre-established points. At each location on the open channel, levels of both the bed and wall of the channel were recorded. The bed-levels of the concrete pipe section were recorded at each manhole after removing the manhole cover and holding the staff in flowing wastewater. The staff was generally placed on the manhole benching. The levelling survey was closed back to the bench-mark (Halcrow BM).

Tables 3.2 and 3.3 give reduced levels for various points on the open channel and the concrete pipeline respectively.

3.2 Non-Destructive Testing of Concrete

Non-destructive testing of concrete pipe was undertaken using an N type Schmidt hammer with impact energy of 2.207 N m. The external surface of pipe was tested between every two manholes, at locations exposed by excavating test pits. Ten different measurements were taken at each location to ensure a representative mean value of rebound number. A similar programme of testing was carried out for each manhole cover on the concrete pipe section.

A total of one hundred and twenty locations were tested and the results for both the concrete pipe and the manhole covers are presented in Tables 3.4 and 3.5 respectively. A table which relates the rebound number value with the cube compressive strength is given in appendix E.

3.3 Concrete Sampling

Samples of concrete were taken from ten locations for laboratory testing and analysis. A drill press mounted core cutting machine was used to obtain cylindrical core specimens from the external surface of the pipe (Photograph 3). Each sample location was carefully selected after reviewing the results of non-destructive testing and ensuring that samples were obtained from each of the construction contracts based on the information available at that time. Table 3.6 gives details of contracts as obtained from the site engineer's record. Details of sample locations are summarised in Table 3.7.

The coring locations were selected on the exposed pipe surfaces after carefully locating embedded reinforcement using a cover meter. The core diameter for the samples was selected based on the spacing of reinforcing steel as determined in this way and after making due allowance for the bit kerf. The length of each core was selected to ensure that the core did not fully penetrate the wall of the pipe and that the remaining pipe wall was sufficiently strong to remain intact during the process of breaking off the core.

Concrete cores of 83 mm diameter and 100 mm nominal length were obtained at ten locations for a total of 16 cores. A sample of plaster from the open channel was also obtained. Details of samples and laboratory testing are given in Table 3.8. Each sampling location was subsequently repaired with fresh mortar prepared with sulphate resisting cement (Photograph 4).

3.4 Water Testing

In order to establish certain effluent quality parameters which can affect chemical attack on the concrete surface, limited on-site testing of water was undertaking at a number of locations. The results of water testing is given in Table 3.9.

3.5 Hydrogen Sulphide Testing

Although measurement of Hydrogen Sulphide (H_2S) was not included in the programme, it was considered important to measure the gas levels in order to assess the potential of sulphate attack on concrete. Hydrogen sulphide was measured at three different locations with Gastec detector tubes. The results are presented in Table 3.10

3.6 Visual Inspection

Although the flowing water and very high levels of toxic gases in the pipe made it impossible to inspect the quality of work from inside, the condition of concrete was visually examined at each manhole after removing the cover. Since they could be readily examined, manhole covers were particularly inspected for sulphate attack originating from gases generated due to the effluent. A qualitative assessment of the condition of 24 concrete manhole covers and of concrete pipe visible in the selected manholes was recorded and the observations are recorded in Table 3.11. In order to examine the quality of concrete pipes, the pipe surface was exposed between every two manholes and was examined for any defects in construction including condition of joints where these were exposed. The quality of construction and the extent of chemical attack at various locations was also recorded by taking photographs.

3.7 Other Information

During the field work, starting with the opening meeting, the following information was verbally requested from KTWMA and it was requested in writing on 12 May.

1. Construction related technical specifications including concrete mix design
2. Information on any modifications made in the design during the construction operation
3. Details of pipes sections constructed with Ordinary Portland Cement or Sulphate Resisting Cement
4. Any correspondence on the use of cement type
5. Testing results of concrete including slump test and cube tests
6. Record of reinforcement cage weight
7. Wastewater testing results
8. Test results for hydraulic testing of pipes
9. Test results for cement powder (both physical and chemical testing

results)

10 Length of pipe sections completed by each contractor

None of this information was received.

Throughout the field work, interviews were conducted with the KTWMA site staff. Mr. Habibullah, representative of Tanzo (one of the construction contractors), was also interviewed with particular emphasis on the methods of construction used. Salient points from these interviews formed the basis for our understanding of the construction works.

HP's site engineer Mr Naveed Ahmed visited the KTWMA offices daily during the field work in order to inform the concerned KTWMA staff regarding site activities.

During the field work, the site was visited by the ANPD UNIDO, the NPD UNIDO, the PD KTWMA, the XEN KTWMA, both SDOs and a Sub Engineer. The site was also visited by a delegation from UNDP.

On 13 May 97, a closing meeting was held with the KTWMA Project Director, Mr. Rana Rasheed, and Executive Engineer, Mr. Abdul Sattar Lillah in which a list of information required from the site staff was also submitted.

4 LABORATORY TESTING

Laboratory testing of concrete samples taken from the pipeline and open channel was carried out at three different specialised laboratories. The following table presents the laboratory selected for each type of test. Details of the test methods and test results are presented in the subsequent sections.

Test Type	Testing Laboratory
Compressive Strength of Concrete	WAPDA Central Materials Testing Laboratory, Lahore
Chemical Analysis of Cementitious Materials	Geoscience Laboratory, Geological Survey of Pakistan, Islamabad
Magnesium Sulphate Soundness Test on Concrete	WAPDA Central Materials Testing Laboratory, Lahore
Petrographic Examination of Concrete Aggregates	Department of Geology, Punjab University, Lahore

4.1 Compressive Strength of Concrete Samples

The compressive strength of concrete samples was tested in accordance with ASTM C42-94 "Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete". The method covers obtaining, preparing and testing cores drilled from concrete for compressive and splitting tensile strength determination. The concrete cores were selected to ensure that the test specimen were free from any abnormal defects and did not include any embedded reinforcement.

The length and diameter of the cores obtained was determined by the wall thickness of the pipe and the spacing of reinforcement as discussed in Section 3. The samples obtained did not therefore conform to the ASTM C42 requirement that samples should have a minimum diameter of 102mm. The samples were cut into 50 mm cubes from the cores. The cubes were then tested for compressive strength.

Ten samples of concrete were tested for compressive strength. The results of the compressive strength tests are presented in Table 4.1.

4.2 Chemical Analysis of Cementitious Materials

The chemical analysis of fresh Ordinary Portland or Sulphate Resisting Cement is specified in British Standard BS 4550:Part 2 1970 "Methods of Testing Cement - Chemical Tests". There are however no standard tests for carrying out the chemical testing of cement in in-place concrete.

The procedure used for the present programme was based on ASTM C85 "Test for Cement Content of Hardened Cement Concrete". This method involved heating a sample of concrete to 1000°C which led to disintegration of the sample. The finer fraction of the sample was then sieved to obtain cement dust. Unavoidably, this included some of the concrete sand as well. The finer fraction of the disintegrated sample was tested for chemical composition in accordance with BS 4550. The samples were analysed using XRF for all major elements. SO_3 and Cl contents were determined by the press pellet method.

The key constituents that allow discrimination between Sulphate Resisting and Ordinary Portland Cement are the content of Tricalcium Aluminate (C_3A), Magnesium Oxide (MgO) and the mass of Sulphur as SO_4. The latter two parameters are determined directly while the C_3A content is determined from Bogue's equation:

$$C_3A = 2.65\ (Al_2O_3) - 1.69\ (Fe_2O_3)\ \%$$

Three samples of concrete and one sample of plaster from the open channel were tested. The results of the chemical analysis tests are presented in appendix D. The reported results are compared with the values typically found in cement (Table 4.2).

4.3 Magnesium Sulphate Soundness

This test is normally used for testing the soundness of concrete aggregates for selection for use in concrete structures. The standard test method is specified in ASTM C88 "Test for Soundness of Aggregates by Use of Sodium Sulphate or Magnesium Sulphate". For the present study , this test has been modified to act as an accelerated durability test on concrete samples. The objective of the modified test is to expose samples of concrete by immersion in a magnesium sulphate solution and to observe any deterioration of the concrete under these conditions. The solutions used and the procedure for immersion and drying are based on ASTM C88. The procedure used for describing sample deterioration is based on the Geomechanics Durability Classification developed by the Council for Scientific and Industrial Research (CSIR), South Africa for describing the deterioration of prismatic rock specimens.

Four selected samples of concrete were tested in accordance with the detailed methodology presented in appendix B. The results of the tests are presented in appendix B and summarised in Table 4.3.

4.4 Petrographic Examination of Aggregate

The test is intended to assess the long term durability of concrete on the basis of the types of aggregate present. The assessment is based on performance data regarding the durability of various rock types and minerals when used as concrete aggregate and exposed to chemical reaction with either alkalis in the cement or with aggressive agents such as seawater or wastewater.

Samples of concrete were subjected to petrographic examination of fine and coarse aggregates. The testing included visual macroscopic examination of specimens, thin section examination under normal and polarised light for identification of mineral types and assessment of mineral frequency by point count methods.

Three samples were subjected to petrographic examination. The results of the tests are presented in appendix C and summarised in Table 4.4.

4.5 Evaluation of Testing Results

4.5.1 Compressive Strength of Concrete

The compressive strength of concrete was tested in-place by non-destructive testing of concrete pipe and manholes. Concrete cores were obtained from ten selected locations and subsequently tested in the laboratory for uniaxial compressive strength.

A graphical representation of non-destructive testing results (Figures 3.3& 3.4) give trends of compressive strength for both types of concrete. It is observed that both the non-destructive testing and laboratory compressive strength testing of concrete follow very similar trends (Figures 3.3 & 4.1). Both types of test show large variations over the length of the concrete pipe line and indicate significantly lower strengths in some sections. These reported results cannot, however, be used to provide an absolute estimate of concrete strength and probably represent upper and lower bounding values. Non-destructive testing results can be affected by the size of aggregate and/or presence of reinforcement close to concrete surface. Due to presence of closely spaced reinforcement, compressive strength testing was undertaken on smaller than normal sized samples, this may have affected the measured strengths even though a size correction has been applied.

4.5.2 Chemical Analysis of Concrete and Plaster

It is understood that the one of the concerns associated with the construction of pipe-line is to confirm the type of cement used in concrete pipes as well as in cement/sand mortar. A detailed chemical analysis of plaster and concrete samples was undertaken. For each sample, the reported results give the composition of major oxides normally present in any type of cement. It is recognised that there is no standard method for the determination of the type of cement present in hardened concrete, and the results of chemical analysis cannot be applied reliably. However in this case comparative analysis of reported results has helped in distinguishing concrete samples prepared with different types of cement.

Sulphate attack on concrete starts when sulphate salts, particularly magnesium and/or sodium sulphate, reacts with tricalcium aluminate (C_3A) to form calcium sulphoaluminate and gypsum. Products of this reaction has increased volume which causes cracking and ultimately disruption of concrete. Generally severe sulphate attack is observed in conditions where concrete is exposed to high levels of sulphate (more than 2000 mg/l of sulphates) accompanied by alternate wetting and drying of concrete surface.

In order to achieve resistance against sulphate attack, sulphate resisting cement has a low content of tricalcium aluminate (C_3A). Ordinary Portland cement generally has a C_3A content in the range of 8 to 10 %. British standard (BS4027:1980) specifies a maximum limit of 3.5 % of C_3A in Sulphate resisting cement with a minimum fineness of 250 m^2/kg. Similarly American Concrete Institute (ACI 350R-89) recommends a maximum limit of 5 % of C_3A in all cementitious material exposed to sulphate levels higher than 1000 mg/l.

The C_3A contents calculated in Table 4.2 for the four samples are affected by the presence of residual aggregate and water in the prepared sample. Therefore the C_3A contents calculated are higher than those of pure cement. Nevertheless the chemical composition of samples MH27-28 and MH54-55 is distinctly different. On a relative basis the C_3A content of sample obtained between box structure 2 and MH-1 is 60%. It is therefore concluded that MH27-28 and MH54-55 contained Ordinary Portland cement and the remaining two samples had Sulphate resisting cement.

4.5.3 Testing of Concrete for Sulphate Soundness

The testing of concrete cubes by cyclic immersion in Magnesium Sulphate solution did not lead to significant observable changes in the sample and the recorded loss of weight of sample was also small. It therefore appears that this test does not provide a sensitive indication of the response of concrete to sulphate attack. This is likely to be a result of the relatively short duration of the test (seven days) in comparison with the periods of months or years over which the sulphate attack phenomenon develops.

4.5.4 Petrographic Examination of Aggregate

The results of this examination can be summarised as follows:

i. A large proportion (43 to 70 percent) of the coarse aggregate in all three samples is potentially prone to Alkali-Silica Reaction (ASR). The susceptibility can only be established by further detailed testing such as the mortar bar test. There is some indication that the presence of acidic fluids on the crown is causing leaching of ASR products in the concrete. However, this beneficial effect is unlikely to prevail in the invert and sidewalls of the pipe.

ii. The fine aggregate does not have any potentially ASR susceptible components. A large proportion of the fine aggregates consists of quartz (52 to 53 percent) and certain types of quartz (strained quartz) may be subject to delayed ASR.

iii. There is some evidence of attack by aggressive, probably acidic, fluids in the samples including leaching of the cement paste together with etching and dissolution of both sand and coarse aggregate particles composed of carbonates.

5 EVALUATION

This section presents an evaluation of the drainage works with respect to the primary objectives of the study of confirming the hydraulic grades of the drainage system, the quality of the completed civil works and the durability of the pipeline and open channel structures. A separate section presents other relevant observations made during the field work.

5.1 Hydraulic Grades

Any evaluation of the as-built hydraulic grades for the open channel and the pipeline should normally be based on a set of construction drawings or a detailed design report. These documents were not made available to the Consultants. The only available information on hydraulic grades for these structures is contained in the "Techno-Economic Study" prepared by Teh Project Hydro Rijeka in July 1992. This appears to be a feasibility level study.

Map 9 of the above referenced study report indicates that the planned grade of both the open channel and the pipeline was 0.4m per 1000m. Figure 3.1 presents the theoretical grade of the pipeline versus the actual measured levels. Details of drainage system sections, showing chainage and levels measured during the field-work, are drawn in PKKTCE02. Overall, the slope of the open channel and the pipeline is steeper than design, however there is evidence that during construction pipe levels were not well controlled and locally the pipeline slopes vary significantly. Such variations occur between and within particular contracts. Figure 3.2 shows the slope of the pipeline between adjacent measurement points, the theoretical slope is also shown.

The capacity of the open channel and pipeline are a function of the overall slope, together with other factors such as roughness and channel geometry. With an overall slope steeper than design, the open channel and pipeline should satisfactorily conduct the design flow. The verification of the hydraulics of the system is, however, not part of the present study.

It is noted that the fact that the slope of the pipe varies as much as it does can have two consequences:

i. Where there are low points in the system, the pipeline and channel will not fully drain under gravity when dewatered for periodic inspection and repair. Dewatering will require pumping from these areas. If waste water is allowed to remain within the pipeline in such areas, it will hinder inspection and be hazardous to workers since it will continue to generate noxious odours and fumes.

ii. Where there are high points in the system, gases such as methane that are lighter than air will accumulate at the crown of the pipe and these gases may be hazardous for workers who may enter the pipe. It may be necessary to provide high volume forced ventilation to remove such accumulations of gases.

There are 13 low points in the channel and pipeline and 15 high points (Figure 3.1).

5.2 Quality of the Completed Civil Works

5.2.1 Pipeline

The pipeline is reported to have been designed in accordance with ASTM C76-90 and constructed using conventional practice for the construction of concrete sewer pipes used by the Punjab Public Health Engineering Department and the Lahore Water and Sanitation Authority. Conventional precast concrete pipe fabrication and pipe laying methods are reported to have been employed. Quality control testing was undertaken during construction, however the records were not made available to the consultants. The following assessment is therefore based on the observations and testing carried out for the present study and discussions with KTWMA site staff.

Visual Inspection

The visual inspection of the pipeline was carried out from manholes and in test pits excavated along the alignment. Overall the pipeline concrete appeared to be of good quality and free of visible construction defects such as cracking, spalling, corrosion, efflorescence, stratification or honeycombing. Concrete surfaces were generally smooth and edges and corners of pipe segments were intact. In about 40 percent of the locations there was some evidence that attack by sulphuric acid produced due to bacterial action in the pipeline (this phenomenon is explained in Section 5.3) has caused some spalling of the section of the pipe exposed in manholes.

Manhole covers were generally found to be of much poorer construction than the pipeline. Many covers showed evidence of honeycombing (Photograph 5) and spalling. About fifty percent of manhole covers showed serious deterioration due to acid attack (Photograph 6) caused by sulphuric acid produced due to bacterial action in the pipeline.

Cement Types

The reported use of various types of cement for the pipeline construction is summarised in Table 5.1. Approximately, 70 percent of the pipeline is reported to have been constructed using Ordinary Portland Cement (OPC). The remainder is constructed using Sulphate Resisting Cement (SRC). Three concrete samples were taken for chemical testing of the cementitious materials. One sample was in a section reported to be constructed with SRC and two from sections constructed with OPC. These tests have confirmed that these cement types were used as reported.

Concrete Quality

It is reported that the cement content in the concrete for the pipeline was 385 kg/m^3 and the water cement ratio varied between 0.4 and 0.45. The mix is reported to be 1:1.5:3. This should result in a durable concrete of acceptable quality and low permeability. Aggregates are reported to have been procured from the Margalla limestone quarries near Islamabad while sand is reported to have been obtained from Lawrencepur and from local sources on the Chenab.

The concrete observed in core samples shows a good distribution of aggregates, sand and cement paste. The coarse aggregate in the core appears to comprise approximately 45 to 50 percent by volume which corresponds with the reported mix design. The concrete in cores has been found to be free of voids and honeycombing. Bonding to reinforcement appears to be good.

The measured non-destructive test results vary significantly along the pipeline length. The rebound values indicate a dense relatively high strength concrete, but the variability of the measured values indicates inadequate construction quality control. Certain sections of the pipeline showed consistently lower rebound values, this may be related to construction practices followed by different contractors.

The measured compressive strengths show similar trends to the non-destructive test results, however the strength values may be affected by the size of the test specimens and appear low for the reported cement content and water cement ratio of the concrete.

Concrete Reinforcement
It is reported that the reinforcing steel was placed in two layers in each pipe section in the form of a welded reinforcing cage made up of circumferential and longitudinal bars of 12.5mm diameter. Reinforcing steel was encountered and recovered in most of the cores. The steel spacing was also checked using a covermeter. The reinforcement spacing was found to be about 100mm for circumferential bars, as reported. The concrete cover to the outer layer of reinforcement steel was observed in cores to be about 40 to 45mm. The covermeter detected a concrete cover of 30 to 40mm. Where reinforcing from the inner layer was encountered in cores the cover to reinforcement from the inside face of the pipe is estimated to be 35 to 40mm.

The concrete cover to reinforcement is in accordance with good practice and with the requirements of ASTM C76-90, which requires the cover to be in excess of 20 mm.

5.2.2 Open Channel

Visual Inspection
The open channel appears to have been constructed using sound conventional construction practices. There was no visual evidence of poor workmanship or deterioration in any section, however since the channel is incomplete, it has not experienced any flow to date. At the location of the plaster sampling, the plaster was found to be 15 mm thick and observations

indicate that this is consistent over the length of the channel.

At 15 locations along the channel, there are constrictions in the channel cross section due to the presence of concrete poles for a power line (Photograph 7). In these locations the channel width reduces from 3m to as little as 1.5m. These constrictions will significantly reduce the capacity of the channel if they remain in place.

Cement Types

It is reported that the channel is constructed from ordinary construction quality bricks with OPC mortar. Plaster on the channel walls and sides is reported to contain SRC over 94 percent of the length of the channel with OPC plaster over the remainder. A sample of plaster was taken from the SRC section of the channel. Chemical testing of this sample confirms that SRC was used.

5.3 Assessment of Pipeline and Channel Durability

The major factors, mechanisms and preventive measures relating to concrete durability are discussed in this section in general terms. Specific evaluation of the Kasur Drainage System follows.

5.3.1 Factors Affecting Concrete Durability

The key durability issues in concrete structures exposed to aggressive waters are:

- Sulphate attack on concrete; this typically occurs due to the reaction of sulphates in water with tricalcium aluminate in cement. The reaction forms ettringite (calcium sulphoaluminate) and gypsum (calcium sulphate). These compounds occupy a greater volume than the compounds that they replace leading to expansion and disruption of the concrete. The use of low water cement ratios, increased cement contents or pozzolanic replacements, sulphate resisting cement and, in extreme cases, inert protective coatings are options for reducing the effects of sulphate attack which leads to a characteristic whitish appearance of concrete.

- Acid attack due to the pH of the effluent; this occurs for liquids with a pH of less than 6.5 and becomes severe at a pH of less than 4.5. Acid attack dissolves and removes a part of the hydrated cement paste leaving a soft and very weak mass. This type of attack can be controlled by adding silica fume to concrete, by replacement of cement with a pozzolanic material such as slag or fly ash or by surface treatment with tar, rubber or bituminous paints, epoxy resins or other agents. Pipe of non corroding materials may also be substituted for concrete pipe.

- Acid attack due to biological development of gases and acids from water containing sulphates flowing in partly full pipes; this is a particular case of acid attack which occurs in sewers carrying domestic or municipal sewers carrying some sulphate leading. It is especially prevalent in warm climates. In this case, sulphates in the water are converted into Hydrogen Sulphide (H_2S) by anaerobic bacteria. The H_2S accumulates in any air space above the fluid flowing in the pipe. Under certain conditions, moisture accumulates in the crown of the pipe by condensation and the H_2S is dissolved in this. Finally, the action of a different bacteria converts the dissolved H_2S into sulphuric acid which attacks the concrete in the crown of the pipe as observed at the end of concrete pipeline (Photograph 8). This is a fairly common phenomenon.

- Chloride attack on concrete; this can occur in marine environments where crystallization of salts can occur in the concrete pores and the pressure of crystallization can lead to expansion and disruption of the concrete. The process is particularly important in areas of capillary rise of water above the high water mark and in zones subjected to wetting and drying. The degree of capillary rise and water penetration is strongly dependent on the permeability of the concrete and the use of high cement contents, low water cement ratios and good construction practices minimise this effect.

- Chloride attack on embedded reinforcement; this is simply caused by penetration of chloride bearing water and chloride ions into concrete and the subsequent corrosion of the reinforcing steel. In addition to the measures described above, to reduce chloride penetration by providing good quality concrete, it is conventional to increase the concrete cover to reinforcement to prevent this.

There are also some complex synergies between these factors, for example, the presence of both sulphate and chloride (as in seawater) prevents sulphate attack (since chloride rich water will dissolve the expansive products which lead to concrete duration) or the use of sulphate resisting cement may, in fact, increase the risk of corrosion by chlorides of embedded reinforcement.

The key preventive measures normally prescribed are:

- The use of good quality concrete with low water cement ratio (< 0.45), high cement contents (typically > 350 kg/m3) and consequently, high density, low porosity and high compressive strength (typically cylinder strengths > 29 MPa). Good quality workmanship which results in a consistent high quality concrete together with adequate consolidation and good curing are also essential.

- The use of sulphate resisting cement in environments where dissolved sulphate levels exceed 1,500 mg/l.

- For exposure to acidic water, sodium silicate additives or coating compounds may be applied, particularly where the pH is less than 6.5. Severe attack is associated with pH less than 4.5.

- It is generally necessary to increase the cover to reinforcement to prevent corrosion of embedded reinforcing steel.

5.3.2 Factors Affecting the Durability of Brickwork

Bricks are porous baked clay tiles that are often prone to attack by water or soils with high levels of dissolved salts. In Pakistan, such problems are encountered in structures in areas of high and saline ground water or saline salts in the Indus plain. The form of the attack on brick masonry comprises of the spalling of the exposed faces of brick. It is generally held that this is due to the build up and crystallisation of salts within the brick. The formation of crystals exerts a pressure within the brick voids with the eventual jacking off of brick material in the direction of least resistance, namely the exposed face of the brick. Salt attack is also believed to occur on the Ordinary Portland Cement mortar used for making brick masonry. This can lead to spalling of the parging and on occasion the spalling of the edges of bricks on either side of the mortar bed.

The essential factor in such deterioration of brick is the crystallisation of salts. Bricks that are immersed in salt bearing water may not be directly attacked, however, bricks subjected to wetting and drying or in areas where evaporation of water leads to crystallisation of salts are particularly prone to attack. Unlike concrete discussed above the porosity of most bricks is high and this effect cannot generally be controlled by substituting with any other conventional type of brick.

5.3.3 Durability of the Kasur Concrete Pipeline

The primary objective of the present programme of works was to confirm that the existing pipeline has been constructed in such a way as to ensure durability under the likely conditions that the system will be exposed to during its lifetime.

In order to discuss the durability of concrete, it is essential to establish the aggressivity of the environmental conditions towards the pipeline concrete. The principle conditions that will affect concrete durability are the composition of the effluent and the quality of soil and ground water outside the pipe.

Unfortunately, no data were available on the actual composition and any variations in raw tannery wastewater and the combined municipal and tannery wastewater currently flowing in the drainage system from the Rohi Nullah. The average quality of raw tannery effluent as stated in the UNDP project document for the KTCP project (1993) and the UNEP document "Tanneries and the Environment" (1991) is as follows:

Parameter	Value reported by UNDP, 1993	Typical Value, UNEP, 1991	Severe Attack Limit
pH	Not reported	9	4.5
Sulphides	102	160	None (leads to acid attack by generation of H_2S and acid in moisture in overhead space)
Sulphates	Not reported	2000	1500 ($MgSO_4$ is most aggressive)
Chloride	Not reported	2500	15 to 20 % by mass of cement in concrete

The aggressivity of ground an ground water along the pipeline is not known, although this should routinely be measured in site investigations for design of a project of this magnitude.

The field work has examined the quality and type of construction of the pipeline as presented in Sections 3 and 4 of this report. The durability of the pipeline with regard to the various types of possible attack is discussed in detail in the following:

Sulphate attack on concrete

The available data on sulphate content of typical raw tannery wastewater would indicate that undiluted tannery effluent may have sufficiently high sulphate levels (>1,500 mg/l) to require the use of sulphate resisting cement in concrete. However the reported concentration of sulphate in typical tannery effluents does not fall into the very aggressive (>2,500 mg/l) or extremely aggressive (>5,000 mg/l) range. The latter limit demarcates the need for the provision of inert protective coatings.

Currently, the flow from the Rohi Nallah has been diverted into the pipeline at Box Structure 1. This flow consists of tannery effluent from the Dingarh cluster combined with most of the municipal wastewater from the city of Kasur and any natural flow within the Nallah. The dilution of raw tannery effluent with municipal effluent (typical sulphate contents of 20 to 50 mg/l) and natural surface water with negligible sulphate contents probably results in a greatly reduced sulphate concentration in the wastewater. It is therefore considered that under present conditions, sulphate attack on the pipeline concrete is unlikely to be a significant issue, however, this needs to be supported by direct testing of the wastewater to establish the range of sulphate contents in practice.

If, at a later date, the pipeline begins to convey treated tannery effluent, the sulphate content of the wastewater may be higher, particularly if municipal effluents and other waters are not added. It is noted that the treatment of the tannery wastewater is unlikely to significantly reduce the levels of dissolved sulphates since the solubility of these salts is high and the planned treatment for chromium recovery and aeration are unlikely to remove these salts. In this case sections of the pipe that are not constructed with sulphate resisting cement may be subject to attack. This also needs to be confirmed by direct testing of the wastewater to establish the range of sulphate contents that may be encountered in practice.

Acid attack on Concrete

Measurements of pH on the effluent currently flowing in the pipeline indicate that it is slightly alkaline, it is therefore not capable of causing acid attack directly. Typical raw tannery effluents are also reported to be alkaline and as a result direct acid attack on the pipeline is unlikely to occur during the life of the pipeline.

There is, however, ample evidence that acid attack due to the liberation of hydrogen sulphide and formation of sulphuric acid due to bacterial action is currently taking place in the pipeline. The petrographic examination of cores, taken from the crown of the pipe, indicates the onset of acid attack in concrete which is at least 25 mm from the inner surface of the pipe. The buildup of secondary precipitates is evident in the crown of the pipe, in manholes and on manhole covers. In about 40 percent of the 21 manholes inspected, there was some evidence that the pipe had suffered spalling due to this process. There has also been serious degradation of a number of manhole covers due to this process, and this has occurred within about six months of the pipe being put into operation. This is believed to be particularly pronounced in manhole covers due to the relatively poor quality of concrete in the covers, however it is considered to be indicative of what may develop in the pipeline in the longer term if the combined tannery and domestic effluent continues to flow in the pipeline.

It is not known what type of effluent will be conveyed in the pipeline in the long term, however, if the effluent contains both organic contamination and dissolved sulphates, the process of acid formation above the water line is likely to continue.

Chloride attack on concrete

The levels of dissolved chlorides in the combined wastewater currently conveyed by the pipeline is likely to be sufficiently low not to cause a concern with regard to durability. In the future even if greatly increased quantities of tannery effluent are included, reported levels of chloride in typical effluents would indicate that chloride levels will not be sufficiently high to lead to problems. The observed and measured quality of concrete and the available cover to reinforcing steel are considered to be adequate to prevent chloride attack.

5.3.4 Durability of the Kasur Open Channel

The open channel portion of the drainage works is believed to be constructed from brick masonry with OPC mortar, the brick walls are plastered with SRC plaster. A final layer of asphaltic or bituminous coating has been applied. The design or specified thickness of the plaster and the asphaltic lining is not known.

The bricks and OPC mortar in the open channel, may over, time be exposed to effluent wastewater with high levels of dissolved salts. It is generally difficult to remove such salts, particularly sulphates and chlorides, from effluents and it is therefore expected that even after treatment the levels of dissolved salts in the effluents will remain high.

Like most site batched and manually applied plasters, the plaster in the open channel is porous and therefore it will allow ingress and capillary movement of contaminated water into the brickwork. The asphaltic lining can act as a waterproofing membrane, however since it is exposed to direct sunlight it will rapidly deteriorate through the loss of its volatile components and it will become brittle and eventually start to leak. In the high temperatures that prevail in Kasur in the summer, the material will also soften and flow, a phenomenon that was observed during the field work. In either case, this lining is considered to be inadequate unless it is regularly repaired and periodically replaced. If the wastewater does enter the brick work it may lead to spalling of the channel. This will primarily lead to the development of extensive damage at or above the waterline in the channel, however it should not seriously impair the structural integrity of the channel if it is repaired periodically.

Plaster made from sulphate resisting cement should not be susceptible to sulphate attack. If, however, sulphate levels are high in the wastewater and the asphalt lining is not maintained, the sulphates may penetrate the porous plaster and attack the OPC mortar in the brickwork, causing it to break up. The magnitude of this kind of effect cannot be predicted, since there is little observational data on such type of attack.

Acid attack is unlikely to be a significant factor in the open channel, since the wastewater will not be acidic and the biological development of acids in the channel is unlikely to occur in the same way as it has developed in the pipeline.

5.4 Other Observations

A number of observations have been made during the field work that are relevant to the present study but are not part of the Consultants scope. These are listed here for the sake of record.

i. There is no detailed design information available for the drainage system, other than a feasibility study prepared in 1992. A report prepared by a UNIDO expert in July 1996, some 8 months after the start of construction, confirmed that a detailed design had not been prepared and repeatedly stressed that this was necessary to allow planning of utility relocations and revisions to the alignment.

ii. It is reported that OPC was used for fabricating the pipe and for the open channel from December 1995 to June 1996. In July, only two months before the end of construction, KTWMA ordered that SRC be used. The implementation of this change resulted in almost a months stoppage of the works. This change in design at a late stage of construction means that 70 percent of the as-built pipeline and 6 percent of the open channel do not conform with the final design basis adopted by KTWMA.

iii. It is reported that the pipeline was bedded using a 1:4:8 lean concrete bedding whereas the vast majority of pipelines are bedded in compacted sand and gravel fill. The use of lean concrete fill is considered unduly conservative and uneconomical for the conditions prevailing in Kasur.

iv. No effluent monitoring results were available to the Consultants and it is believed that such testing has not been carried out. This information is essential for the selection of appropriate construction materials and the evaluation of the as-built system and would normally form a key parameter for the design.

v. There is no system of ventilation provided in the pipeline. This has resulted in the buildup of hydrogen sulphide to levels that are causing acid attack on concrete surfaces and pose a serious hazard to humans and animals.

vi. It is reported that construction quality control practices followed during construction fulfill the requirements of the Public Health Engineering Department specifications, however a number of key routine tests appear not to have been carried out. These include aggregate moisture content and slump tests which are used to control the concrete water cement ratio and workability. In the absence of such testing, the water cement ratio may vary substantially and lead to variations in concrete strength as observed during the present study.

vii. Conventional construction records; including daily reports, field diaries, progress payment records, survey field books, field and laboratory test results were not made available to the Consultants and there is some evidence that only field diaries and limited laboratory testing records may have been maintained. This would normally be considered inadequate for a project of this magnitude.

6 CONCLUSIONS

The following conclusions have been reached on the basis of the field work, field and laboratory testing carried out for this project:

6.1 Hydraulics of Open Channel and Pipeline

- The overall slope of the open channel and the pipeline is steeper than design and it is concluded that these structures should satisfactorily conduct the design flow. There is, however, evidence that pipe levels were not well controlled during construction and, as a result, there are 13 low points and 15 high points in the channel and pipeline.

- At 15 locations along the channel, there are constrictions in the channel cross section. These constrictions will significantly reduce the capacity of the channel if they remain in place.

6.2 Pipeline Concrete

- The pipeline concrete generally appears to be of good quality and free of visible construction defects such as cracking, spalling, corrosion, efflorescence, stratification or honeycombing. Manhole covers were generally found to be of much poorer construction than the pipeline.

- There is ample evidence of acid attack in the crown of the pipeline. This includes the buildup of secondary precipitates on the pipe surface and evidence of acid attack on cement paste and aggregates observed in the petrographic examination. This attack has started weakening of the concrete pipe, observed in about 40 percent of manholes. Evidence of such attack is particularly pronounced in manhole cover concrete which now show extensive spalling and damage to the concrete.

- Approximately, 70 percent of the pipeline is reported to have been constructed using Ordinary Portland Cement (OPC). The remainder is constructed using Sulphate Resisting Cement (SRC). Laboratory tests have confirmed that cement types were used as reported.

- The concrete observed in core samples shows a good distribution of aggregates, sand and cement paste. It appears free of voids and honeycombing. Bonding to reinforcement appears to be good.

- Non-destructive testing has indicated a dense relatively high strength concrete, but the variability of the measured values indicates inadequate construction quality control. Certain sections of the pipeline showed consistently lower compressive strength.

- The reinforcement spacing was found to be about 100 mm for circumferential bars, as reported. The concrete cover to the reinforcement steel was observed in cores to be in accordance with good practice and with the requirements of ASTM C76-90

6.3 Open Channel

- At the location of the plaster sampling, the plaster was found to be 15 mm thick and observations indicate that this is consistent over the length of the channel.

- Plaster on the channel walls and sides is reported to contain SRC over 94 percent of the length of the channel with OPC plaster over the remainder. Chemical testing of this sample confirms that SRC was used.

6.4 Durability of Structures

- Currently, the flow from the Rohi Nallah has been diverted into the pipeline at Box Structure 1. This flow consists of tannery effluent from the Dingarh cluster combined with most of the municipal wastewater from the city of Kasur. Since this results in considerable dilution of tannery effluents, sulphate attack on the pipeline concrete is unlikely to be a significant issue, however, this needs to be supported by direct testing of the wastewater

- If, at a later date, the pipeline begins to convey treated tannery effluent, the sulphate content of the wastewater may be higher. In this case sections of the pipe that are not constructed with sulphate resisting cement may be subject to attack. This also needs to be confirmed by direct testing of the wastewater

- There is ample evidence that acid attack due to the liberation of hydrogen sulphide and formation of sulphuric acid due to bacterial action is currently taking place in the pipeline. In about 40 percent of the 21 manholes inspected, there was some evidence that the pipe had suffered spalling due to this process. There has also been serious degradation of a number of manhole covers due to this process, and this has occurred within about six months of the pipe being put into operation.

- It is understood that the primary effluent treatment plant will only remove 65% of the Biological Oxygen Demand and 55% of the Chemical Oxygen Demand in the effluent. In the presence of remaining organic loading, it is anticipated that the hydrogen sulphide generation will continue to increase, and therefore the likelihood of acid attack on the concrete surface will increase. It is therefore recommended that the design of effluent treatment plant should be reviewed to include the provision of secondary treatment stage in the final design. Moreover in view of the existing National Environmental Quality Standards (NEQS) enforced since July 1996, the present design of treatment plant will not treat the effluent to a quality necessary for the permission from the Environmental Protection Department (EPD) Government of Punjab, to discharge effluent into the Pandoki drain.

- The observed and measured quality of concrete and the available cover to reinforcing steel are considered to be adequate to prevent chloride attack.

- The plaster in the open channel is porous and therefore it will allow ingress and capillary movement of contaminated water into the brickwork. The asphaltic lining can act as a waterproofing membrane, however since it is exposed to direct sunlight it will rapidly deteriorate unless it is routinely maintained and periodically replaced.

- If the wastewater does enter the brick work it may lead to spalling of the channel. This will primarily lead to the development of extensive damage at or above the waterline in the channel, however it should not seriously impair the structural integrity of the channel.

- Acid attack is unlikely to be a significant factor in the open channel.

6.5 Other Observations

- There is no detailed design information available for the drainage system, other than a feasibility study prepared in 1992.

- It is reported that OPC was used for fabricating the pipe and for the open channel from December 1995 to June 1996. In July, only two months before the end of construction, KTWMA ordered that SRC be used. This change in design at a late stage of construction means that 70 percent of the as-built pipeline and 6 percent of the open channel do not conform with the final design basis adopted by KTWMA.

- It is reported that the pipeline was bedded using a 1:4:8 lean concrete bedding. The use of lean concrete fill is considered unduly conservative and uneconomical for the conditions prevailing in Kasur.

- No effluent monitoring results were available to the Consultants and it is believed that such testing has not been carried out. This information is essential for the design.

- There is no system of ventilation provided in the pipeline, this has resulted in the buildup of hydrogen sulphide to levels that are causing acid attack on concrete surfaces and pose a serious hazard to humans and animals.

- A number of construction quality control practices and key routine tests appear not to have been carried out. The variations in concrete quality observed during the present study may result from these practices not being followed.

- Conventional construction records; including daily reports, field diaries, progress payment records, survey field books, field and laboratory test results were not made available to the Consultants and there some evidence that only field diaries and limited laboratory testing records may have been maintained. This would not normally be considered adequate for a project of this magnitude.

Table 3.1

DISTANCES BETWEEN MANHOLES ON CLOSED PIPE SECTION

Section (Halcrow Reference)	Section (Site Staff Reference)	Distance Measured (meters)	Distance (Feet)
Box structure 2 to Manhole 1	Manhole 60 to start of 54" concrete pipe	45	147.64
Manhole 1 to Manhole 2	Manhole 59 to Manhole 60	75	246.06
Manhole 2 to Manhole 3	Manhole 58 to Manhole 59	99.5	326.44
Manhole 3 to Manhole 4	Manhole 57 to Manhole 58	99.5	326.44
Manhole 4 to Manhole 5	Manhole 56 to Manhole 57	99.4	326.12
Manhole 5 to Manhole 6	Manhole 55 to Manhole 56	99.3	325.79
Manhole 6 to Manhole 7	Manhole 54 to Manhole 55	99.4	326.12
Manhole 7 to Manhole 8	Manhole 53 to Manhole 54	99.5	326.44
Manhole 8 to Manhole 9	Manhole 52 to Manhole 53	85	278.87
Manhole 9 to Manhole 10	Manhole 51 to Manhole 52	70.3	230.64
Manhole 10 to Manhole 11	Manhole 50 to Manhole 51	99.8	327.43
Manhole 11 to Manhole 12	Manhole 49 to Manhole 50	99.7	327.10
Manhole 12 to Manhole 13	Manhole 48 to Manhole 49	99.4	326.12
Manhole 13 to Manhole 14	Manhole 47 to Manhole 48	99.5	326.44
Manhole 14 to Manhole 15	Manhole 46 to Manhole 47	99.5	326.44
Manhole 15 to Manhole 16	Manhole 45 to Manhole 46	92	301.84
Manhole 16 to Manhole 17	Manhole 44 to Manhole 45	63.2	207.35
Manhole 17 to Box Structure 3	Box Structure 2 to Manhole 44	63.75	209.15
Box Structure 3 to Box Structure 4	Box Structure 1 to Box Structure 2	79.75	261.65
Box Structure 4 to Manhole 18	Manhole 43 to Box structure 1	123.7	405.84
Manhole 18 to Manhole 19	Manhole 42 to Manhole 43	33.2	108.92
Manhole 19 to Manhole 20	Manhole 41 to Manhole 42	99.2	325.46
Manhole 20 to Manhole 21	Manhole 40 to Manhole 41	106.7	350.07
Manhole 21 to Manhole 22	Manhole 39 to Manhole 40	106.8	350.39
Manhole 22 to Manhole 23	Manhole 38 to Manhole 39	99.5	326.44
Manhole 23 to Manhole 24	Manhole 37 to Manhole 38	99.5	326.44
Manhole 24 to Manhole 25	Manhole 36 to Manhole 37	99.4	326.12
Manhole 25 to Manhole 26	Manhole 35 to Manhole 36	99	324.80
Manhole 26 to Manhole 27	Manhole 34 to Manhole 35	99.5	326.44
Manhole 27 to Manhole 28	Manhole 33 to Manhole 34	99.5	326.44
Manhole 28 to Manhole 29	Manhole 32 to Manhole 33	99.5	326.44
Manhole 29 to Manhole 30	Manhole 31 to Manhole 32	97.1	318.57
Manhole 30 to Manhole 31	Manhole 30 to Manhole 31	99.7	327.10
Manhole 31 to Manhole 32	Manhole 29 to Manhole 30	99.6	326.77
Manhole 32 to Manhole 33	Manhole 28 to Manhole 29	58	190.29
Manhole 33 to Manhole 34	Manhole 27 to Manhole 28	99.5	326.44
Manhole 34 to Manhole 35	Manhole 26 to Manhole 27	99.5	326.44
Manhole 35 to Manhole 36	Manhole 25 to Manhole 26	99.3	325.79
Manhole 36 to Manhole 37	Manhole 24 to Manhole 25	114.7	376.31
Manhole 37 to Manhole 38	Manhole 23 to Manhole 24	99.3	325.79
Manhole 38 to Manhole 39	Manhole 22 to Manhole 23	99.3	325.79
Manhole 39 to Manhole 40	Manhole 21 to Manhole 22	99.5	326.44
Manhole 40 to Manhole 41	Manhole 20 to Manhole 21	96.8	317.59
Manhole 41 to Manhole 42	Manhole 19 to Manhole 20	97.5	319.88
Manhole 42 to Manhole 43	Manhole 18 to Manhole 19	97	318.24
Manhole 43 to Manhole 44	Manhole 17 to Manhole 18	96.5	316.60
Manhole 44 to Manhole 45	Manhole 16 to Manhole 17	99	324.80
Manhole 45 to Manhole 46	Manhole 15 to Manhole 16	99	324.80
Manhole 46 to Manhole 47	Manhole 14 to Manhole 15	102.3	335.63
Manhole 47 to Manhole 48	Manhole 13 to Manhole 14	99	324.80
Manhole 48 to Manhole 49	Manhole 12 to Manhole 13	99	324.80
Manhole 49 to Manhole 50	Manhole 11 to Manhole 12	99	324.80
Manhole 50 to Manhole 51	Manhole 10 to Manhole 11	99.4	326.12
Manhole 51 to Manhole 52	Manhole 9 to Manhole 10	99.3	325.79
Manhole 52 to Manhole 53	Manhole 8 to Manhole 9	99.3	325.79
Manhole 53 to Manhole 54	Manhole 7 to Manhole 8	99.3	325.79
Manhole 54 to Manhole 55	Manhole 6 to Manhole 7	99.3	325.79
Manhole 55 to Manhole 56	Manhole 5 to Manhole 6	102.2	335.30
Manhole 56 to Manhole 57	Manhole 4 to Manhole 5	99.5	326.44
Manhole 57 to Manhole 58	Manhole 3 to Manhole 4	99.5	326.44
Manhole 58 to Manhole 59	Manhole 2 to Manhole 3	99.3	325.79
Manhole 59 to Manhole 60	Manhole 1 to Manhole 2	99	324.80
Manhole 60 to Final outfall	Final Outfall to Manhole 1	34.7	113.85
Total Distance		5915.4	19,407.48

HALCROW

Table 3.2

REDUCED LEVELS FOR OPEN CHANNEL

Chainage (meters)	RD (Feet)	Reduced Level (meters)		Depth of Channel (meters)
		Bed	Side wall	
-1659.25	248.51	196.53	198.06	1.53
-1550	244.93	196.53	197.98	1.45
-1450	241.65	196.49	197.94	1.45
-1350	238.37	196.44	198.07	1.63
-1250	235.09	196.48	198.1	1.62
-1150	231.80	196.39	198.08	1.69
-1050	228.52	196.35	197.99	1.64
-950	225.24	196.31	197.95	1.64
-830	221.31	196.305	197.935	1.63
-730	218.02	196.335	197.805	1.47
-700	217.04	196.205	197.675	1.47
-600	213.76	196.18	197.63	1.45
-500	210.48	196.14	197.61	1.47
-400	207.20	196.145	197.625	1.48
-300	203.92	196.075	197.735	1.66
-200	200.64	196.04	197.64	1.60
-166.36	199.53	195.95	197.65	1.7
-55.16	195.88	195.995	198.015	2.02
36" pipe Box Structure1	194.87	N/M	N/A	N/A
0, Start of 54" pipe, Box Structure2 Halcrow Reference Manhole	194.07	195.99	198.25	

Table 3.3

REDUCED BED-LEVELS FOR CONCRETE PIPE

Location (Halcrow Reference)	Chainage (meters)	RD (Feet)	Level (meters)
Start of 54" pipe, Box Structure 2, Halcrow Reference Manhole	0	194.07	195.99
Manhole 01	45	192.60	195.95
Manhole 02	120	190.14	195.93
Manhole 03	219.5	186.87	195.92
Manhole 04	319	183.61	195.84
Manhole 05	418.4	180.35	195.77
Manhole 06	517.7	177.09	195.77
Manhole 07	617.1	173.83	195.7
Manhole 08	716.6	170.56	195.72
Manhole 09	801.6	167.78	195.63
Manhole 10	871.9	165.47	195.65
Manhole 11	971.7	162.19	195.57
Manhole 12	1071.4	158.92	195.58
Manhole 13	1170.8	155.66	195.55
Manhole 14	1270.3	152.40	195.5
Manhole 15	1369.8	149.13	195.53
Manhole 16	1461.8	146.12	195.45
Manhole 17	1525	144.04	195.42
54" pipe at Box Structure3	1588.75	141.95	195.4
54" pipe at Box Structure4	1668.5	139.33	195.29
Manhole 18	1792.2	135.28	195.32
Manhole 19	1825.4	134.19	195.15
Manhole 20	1924.6	130.93	195.01
Manhole 21	2031.3	127.43	194.98
Manhole 22	2138.1	123.93	194.95
Manhole 23	2237.6	120.66	194.87
Manhole 24	2337.1	117.40	194.9
Manhole 25	2436.5	114.14	194.84
Manhole 26	2535.5	110.89	194.75
Manhole 27	2635	107.62	194.66
Manhole 28	2734.5	104.36	194.63
Manhole 29	2834	101.10	194.57
Manhole 30	2931.1	97.91	194.6

Continued on next page

Table 3.3 (Continued)

REDUCED BED-LEVELS FOR CONCRETE PIPE

Location (Halcrow Reference)	Chainage (meters)	RD (Feet)	Level (meters)
Manhole 31	3030.8	94.64	194.49
Manhole 32	3130.4	91.37	194.49
Manhole 33	3188.4	89.47	194.48
Manhole 34	3287.9	86.20	194.37
Manhole 35	3387.4	82.94	194.38
Manhole 36	3486.7	79.68	194.32
Manhole 37	3601.4	75.92	194.21
Manhole 38	3700.7	72.66	194.015
Manhole 39	3800	69.40	194.06
Manhole 40	3899.5	66.14	194.07
Manhole 41	3996.3	62.96	194.05
Manhole 42	4093.8	59.76	193.97
Manhole 43	4190.8	56.58	193.96
Manhole 44	4287.3	53.42	193.86
Manhole 45	4386.3	50.17	193.88
Manhole 46	4485.3	46.92	193.84
Manhole 47	4587.6	43.56	193.8
Manhole 48	4686.6	40.31	193.72
Manhole 49	4785.6	37.07	193.66
Manhole 50	4884.6	33.82	193.54
Manhole 51	4984	30.56	193.56
Manhole 52	5083.3	27.30	193.41
Manhole 53	5182.6	24.04	193.39
Manhole 54	5281.9	20.78	193.32
Manhole 55	5381.2	17.53	193.27
Manhole 56	5483.4	14.17	193.28
Manhole 57	5582.9	10.91	193.2
Manhole 58	5682.4	7.64	193.25
Manhole 59	5781.7	4.39	193.22
Manhole 60	5880.7	1.14	193.225
Outfall point	5915.4	0.00	193.185

Note: Levels measured on manhole benching

Table 3.4

NON-DESTRUCTIVE TEST RESULTS FOR CONCRETE PIPELINE

Section (Halcrow Reference)	Chainage (meters)	RD (Feet)	Hammer Readings 1	2	3	4	5	6	7	8	9	10	Mean
Box Structure2 to Manhole 1	20.7	193.40	37	28	34	33	44	34	32	34	36	38	35
Manhole 1 to Manhole 2	85.5	191.27	34	42	42	38	47	40	44	44	38	44	41.3
Manhole 2 to Manhole 3	207	187.28	47	42	35	35	42	38	33	32	33	34	37.1
Manhole 3 to Manhole 4	298.1	184.29	35	38	33	32	37	36	31	36	25	35	33.8
Manhole 4 to Manhole 5	377.15	181.70	28	28	46	34	26	35	33	42	37	38	34.7
Manhole 5 to Manhole 6	434.4	179.82	42	36	36	38	35	36	37	38	34	35	36.7
Manhole 6 to Manhole 7	536.3	176.48	46	36	35	32	34	46	35	36	36	44	38
Manhole 7 to Manhole 8	655.9	172.56	47	30	38	35	41	38	42	34	38	38	38.1
Manhole 8 to Manhole 9	774.2	168.67	42	42	54	42	41	48	45	35	38	41	42.8
Manhole 9 to Manhole 10	838.3	166.57	45	46	46	48	49	52	47	46	44	40	46.3
Manhole 10 to Manhole 11	927.2	163.65	39	40	30	36	34	35	44	34	26	38	35.6
Manhole 11 to Manhole 12	1041.4	159.91	34	38	32	34	30	38	42	46	33	37	36.4
Manhole 12 to Manhole 13	1114	157.53	42	44	40	40	50	42	43	44	52	36	43.3
Manhole 13 to Manhole 14	1225.6	153.86	38	28	38	34	39	50	38	37	39	42	38.3
Manhole 14 to Manhole 15	1345.2	149.94	50	50	37	40	46	52	34	52	38	50	44.9
Manhole 15 to Manhole 16	1411.2	147.78	42	37	32	38	40	40	44	30	36	37	37.6
Manhole 16 to Manhole 17	1494.7	145.04	48	46	40	37	48	45	42	38	44	43	43.1
Manhole 17 to Box Structure 3	1545.3	143.38	47	50	46	46	47	46	44	48	52	52	47.8
Box Structure 4 to Manhole 18	1767.9	136.07	44	41	42	44	36	41	54	42	38	42	42.4
Manhole 18 to Manhole 19	1814.2	134.55	34	41	42	41	40	33	38	38	44	38	38.9
Manhole 19 to Manhole 20	1851.4	133.33	34	40	44	35	44	51	40	38	34	38	39.8
Manhole 20 to Manhole 21	1953.4	129.99	34	40	36	28	32	28	28	36	32	35	32.9
Manhole 21 to Manhole 22	2092.6	125.42	37	36	42	48	37	40	43	36	34	36	38.9
Manhole 22 to Manhole 23	2167.8	122.95	43	43	48	38	39	40	48	44	42	48	43.3
Manhole 23 to Manhole 24	2287	119.04	38	41	38	44	34	38	40	42	42	35	39.2
Manhole 24 to Manhole 25	2372.2	116.25	36	37	32	39	39	34	23	42	41	46	36.9
Manhole 25 to Manhole 26	2491.6	112.33	38	34	33	39	40	36	38	46	36	38	37.8
Manhole 27 to Manhole 28	2664	106.67	33	32	35	37	34	34	29	33	34	31	33.2
Manhole 28 to Manhole 29	2780	102.87	42	44	42	34	46	42	37	46	44	41	41.8
Manhole 29 to Manhole 30	2891.5	99.21	48	42	28	41	42	40	42	40	40	38	40.1
Manhole 30 to Manhole 31	2955.6	97.11	41	35	41	32	45	44	39	41	48	38	40.4
Manhole 31 to Manhole 32	3067.8	93.43	42	44	46	44	38	46	36	38	45	40	41.9
Manhole 32 to Manhole 33	3170.7	90.05	44	44	44	53	45	44	47	47	40	52	46
Manhole 33 to Manhole 34	3260.6	87.10	42	44	38	43	44	51	49	37	49	44	44.1
Manhole 34 to Manhole 35	3326.4	84.94	36	39	36	46	44	44	43	38	42	44	41.2
Manhole 35 to Manhole 36	3420.7	81.85	42	38	42	39	36	42	36	37	38	43	39.3
Manhole 36 to Manhole 37	3542.1	77.86	40	46	52	41	48	44	43	45	43	40	44.2
Manhole 37 to Manhole 38	3640	74.65	44	40	43	45	40	46	42	41	44	41	42.6
Manhole 38 to Manhole 39	3760.2	70.71	49	43	45	50	47	46	49	47	46	42	46.4
Manhole 39 to Manhole 40	3815.3	68.90	42	39	46	44	50	40	39	42	41	40	42.3
Manhole 40 to Manhole 41	3944.7	64.66	38	43	50	38	39	40	39	37	44	46	41.4
Manhole 41 to Manhole 42	4011.3	62.47	48	46	47	44	46	44	50	41	47	42	45.5
Manhole 42 to Manhole 43	4129.6	58.59	32	34	41	35	40	39	35	39	37	36	36.8
Manhole 43 to Manhole 44	4216.2	55.75	44	45	44	48	42	45	38	46	37	41	43
Manhole 44 to Manhole 45	4322.6	52.26	33	36	48	36	35	49	40	44	44	44	40.9

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Table 3.4 (continued)

NON-DESTRUCTIVE TEST RESULTS FOR CONCRETE PIPELINE

Section (Halcrow Reference)	Chainage (meters)	RD (Feet)	Hammer Readings										Mean
			1	2	3	4	5	6	7	8	9	10	
Manhole 45 to Manhole 46	4420.3	49.05	48	45	44	49	46	48	46	45	46	47	46.4
Manhole 46 to Manhole 47	4506.9	46.21	46	54	38	39	49	39	46	48	42	49	45
Manhole 47 to Manhole 48	4615.4	42.65	42	44	44	44	53	38	46	41	39	36	42.7
Manhole 48 to Manhole 49	4721.7	39.16	41	38	41	33	38	48	39	43	40	43	40.4
Manhole 49 to Manhole 50	4815	36.10	44	44	45	43	44	40	41	44	38	42	42.5
Manhole 50 to Manhole 51	4900.2	33.31	38	36	42	39	43	43	40	40	46	48	41.5
Manhole 51 to Manhole 52	5012	29.64	41	38	47	42	42	38	47	42	42	43	42.2
Manhole 53 to Manhole 54	5222.4	22.74	46	46	46	47	33	24	22	32	23	20	33.9
Manhole 54 to Manhole 55	5322.7	19.45	46	50	44	44	48	48	44	46	52	40	46.2
Manhole 55 to Manhole 56	5419.5	16.27	30	40	40	46	36	34	40	32	42	36	37.6
Manhole 56 to Manhole 57	5543.2	12.21	37	40	32	38	36	38	40	35	48	34	37.8
Manhole 57 to Manhole 58	5651.8	8.65	40	46	40	26	38	40	38	44	32	41	38.5
Manhole 58 to Manhole 59	5715.6	6.56	33	44	39	22	38	42	26	40	42	49	37.5
Manhole 59 to Manhole 60	5801.5	3.74	36	26	44	40	36	38	24	36	40	38	35.8
Manhole 60 to Final outfall	5915.4	0.00	38	36	36	42	40	38	38	38	33	38	37.7

Table 3.5

NON-DESTRUCTIVE TEST RESULTS FOR MANHOLE COVERS

Location (Halcrow Reference)	Chainage (meters)	RD (Feet)	Hammer Readings 1	2	3	4	5	6	7	8	9	10	Mean
Manhole 1	45	192.60	34	32	34	32	30	28	31	28	32	32	31.3
Manhole 2	120	190.14	31	38	33	33	32	26	36	34	34	36	33.3
Manhole 3	219.5	186.87	28	27	23	28	22	17	27	26	34	36	26.8
Manhole 4	319	183.61	32	27	34	26	24	32	26	25	24	28	27.8
Manhole 5	418.4	180.35	33	32	30	37	30	32	32	28	30	32	31.6
Manhole 6	517.7	177.09	34	31	26	28	29	32	28	25	34	30	29.7
Manhole 7	617.1	173.83	22	31	36	28	31	32	28	34	31	30	30.3
Manhole 8	716.6	170.56	33	34	37	34	26	28	27	28	32	31	31
Manhole 9	801.6	167.78	26	26	32	25	18	19	24	24	22	28	24.4
Manhole 10	871.9	165.47	30	27	30	35	32	32	26	30	26	30	29.8
Manhole 11	971.7	162.19	26	28	27	29	21	26	32	30	30	27	27.6
Manhole 12	1071.4	158.92	33	32	32	32	32	33	33	36	29	36	32.8
Manhole 13	1170.8	155.66	24	28	26	22	20	16	28	30	28	22	24.4
Manhole 14	1270.3	152.40	36	33	38	36	36	36	36	32	34	31	34.8
Manhole 15	1369.8	149.13	25	28	25	34	33	30	28	32	32	31	29.8
Manhole 16	1461.8	146.12	32	28	26	28	32	29	32	29	26	24	28.6
Manhole 17	1525	144.04	40	39	32	42	45	41	42	46	42	42	41.1
Manhole 18	1792.2	135.28	28	34	30	32	28	30	28	32	31	33	30.6
Manhole 19	1825.4	134.19	24	20	20	29	27	29	22	22	36	26	25.5
Manhole 20	1924.6	130.93	30	26	24	22	26	20	29	24	31	28	26
Manhole 21	2031.3	127.43	20	19	20	17	18	24	20	19	20	20	19.7
Manhole 22	2138.1	123.93	20	22	26	27	23	21	21	18	19	19	21.6
Manhole 23	2237.6	120.66	27	29	33	23	31	30	34	29	26	31	29.3
Manhole 24	2337.1	117.40	31	26	25	29	28	30	34	30	29	29	29.1
Manhole 25	2436.5	114.14	24	20	24	22	20	32	22	16	22	24	22.6
Manhole 26	2535.5	110.89	26	31	26	23	24	30	26	27	16	26	25.5
Manhole 28	2734.5	104.36	32	29	30	31	30	30	33	31	25	31	30.2
Manhole 29	2834	101.10	22	24	20	22	23	26	19	21	23	24	22.4
Manhole 30	2931.1	97.91	27	20	23	21	26	31	26	23	18	15	23
Manhole 31	3030.8	94.64	38	32	35	28	38	40	40	34	32	36	35.3
Manhole 32	3130.4	91.37	26	22	21	24	28	29	30	36	23	25	26.4
Manhole 33	3188.4	89.47	38	40	38	37	41	36	26	46	41	42	38.5
Manhole 34	3287.9	86.20	34	16	25	18	22	20	25	20	15	13	20.8
Manhole 35	3387.4	82.94	18	22	24	18	18	26	17	20	18	18	19.9
Manhole 36	3486.7	79.68	28	31	25	28	28	24	22	30	30	28	27.4
Manhole 37	3601.4	75.92	19	22	20	22	18	22	20	20	20	23	20.6
Manhole 38	3700.7	72.66	26	24	28	24	30	24	22	25	29	28	26
Manhole 39	3800	69.40	26	27	26	24	24	22	24	26	26	24	24.9
Manhole 40	3899.5	66.14	27	26	24	24	22	22	26	27	26	28	25.2
Manhole 41	3996.3	62.96	22	23	25	20	20	20	24	26	20	24	22.4
Manhole 42	4093.8	59.76	22	24	18	22	24	28	18	24	22	26	22.8
Manhole 43	4190.8	56.58	24	24	23	24	22	25	19	22	26	20	22.9
Manhole 44	4287.3	53.42	22	20	22	20	22	17	20	19	22	22	20.6
Manhole 45	4386.3	50.17	24	22	24	24	25	22	24	25	22	24	23.6

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Table 3.5 (Continued)

NON-DESTRUCTIVE TEST RESULTS FOR MANHOLE COVERS

Location (Halcrow Reference)	Chainage (meters)	RD (Feet)	Hammer Readings 1	2	3	4	5	6	7	8	9	10	Mean
Manhole 46	4485.3	46.92	32	30	24	26	24	19	28	33	21	25	26.2
Manhole 47	4587.6	43.56	25	21	24	28	21	28	24	26	25	24	24.6
Manhole 48	4686.6	40.31	22	32	28	34	36	24	24	26	30	28	28.4
Manhole 49	4785.6	37.07	28	38	34	38	36	26	38	34	32	36	34
Manhole 50	4884.6	33.82	22	25	21	28	26	24	22	22	25	22	23.7
Manhole 51	4984	30.56	20	22	24	28	30	22	26	24	23	27	24.6
Manhole 52	5083.3	27.30	32	32	38	27	28	34	32	30	26	30	30.9
Manhole 53	5182.6	24.04	30	28	30	34	31	30	34	29	27	26	29.9
Manhole 54	5281.9	20.78	32	33	43	40	37	38	39	38	38	40	37.8
Manhole 55	5381.2	17.53	31	31	35	30	35	32	32	28	36	36	32.6
Manhole 56	5483.4	14.17	25	30	30	28	30	32	28	30	29	32	29.4
Manhole 57	5582.9	10.91	27	30	30	28	27	28	24	28	32	31	28.5
Manhole 58	5682.4	7.64	40	37	36	34	36	36	36	36	28	31	35
Manhole 59	5781.7	4.39	26	24	22	25	28	25	26	26	30	28	26
Manhole 60	5880.7	1.14	21	21	24	20	23	22	29	26	24	24	23.4

Table 3.6

LENGTHS OF SECTIONS CONSTRUCTED BY VARIOUS CONTRACTORS

Section (as reported by site staff)		Reduced Distance (Feet)		Length of Section		Name of Contractor	Reported Type of Cement Used
From	To	From	To	(Feet)	(meters)		
RD 0	RD 1.6	0	1.6	160	48.77	Haji Gul Muhammad & Sons	Ordinary Portland Cement
Manhole 01	Manhole 16	1.60	50.17	4,856.73	1,480.33	Akhtar Hussain	Ordinary Portland Cement / Slag Cement
Manhole 16	Manhole 20	50.17	62.96	1,279.53	390.00	Akhtar Hussain	Sulphate Resisting Cement
Manhole 20	Manhole 22	62.96	69.40	644.03	196.30	Akhtar Hussain	Ordinary Portland Cement / Slag Cement
Manhole 22	Manhole 24	69.40	76.2	679.71	207.18	Akhtar Hussain	Sulphate Resisting Cement
RD 76.2	RD 131.2	76.2	131.2	5,500.00	1,676.40	Haji Gul Muhammad & Sons	Ordinary Portland Cement / Slag Cement (some part with Sulphate Resisting Cement)
RD 131.2	RD 136	131.2	136	480.00	146.30	Tanzo Engineers	Sulphate Resisting Cement
RD 136	RD 147	136	147	1,100.00	335.28	Chaudary Construction	Sulphate Resisting Cement
RD 147	RD 173	147	173	2,600.00	792.48	Tanzo Engineers	Ordinary Portland Cement / Slag Cement
RD 173	RD 195	173	195	2,200.00	670.56	Tanzo Engineers	Sulphate Resisting Cement
RD 195	RD 195.8	195	195.8	80.00	24.38	Chaudary Construction	Sulphate Resisting Cement
RD 195.8	RD 198.05	195.8	198.05	225.00	68.58	Haji Gul Muhammad & Sons	Sulphate Resisting Cement
RD 198.05	RD 245	198.05	245	4,695.00	1,431.04	Marigold Engineers	Sulphate Resisting Cement
RD 245	RD 248.5	245	248.5	350.00	106.68	Marigold Engineers	Ordinary Portland Cement / Slag Cement (Sulphate Resisting Cement was used in plaster)
RD 248.5	RD 256	248.5	256	750.00	228.60	Chaudary Construction	Sulphate Resisting Cement

Table 3.7

Details of Concrete/Plaster Sampling Program

Sample Location (HALCROW Reference)	Chainage (meters)	RD (Feet)	Contractor	Reported Type of Cement
Open Channel	-224.5	201.44	Marigold Engineers	Sulphate Resisting
Box Structure2 to Manhole 1	20.7	193.40	Tanzo Engineers	Sulphate Resisting
Manhole 9 to Manhole 10	838.3	166.57	Tanzo Engineers	Ordinary Portland
Manhole 15 to Manhole 16	1411.2	147.78	Tanzo Engineers	Ordinary Portland
Manhole 20 to Manhole 21	1953.4	129.99	Haji Gul Muhammad & Sons	Ordinary Portland
Manhole 27 to Manhole 28	2664	106.67	Haji Gul Muhammad & Sons	Ordinary Portland
Manhole 35 to Manhole 36	3420.7	81.85	Haji Gul Muhammad & Sons	Ordinary Portland
Manhole 40 to Manhole 41	3944.7	64.66	Akhtar Hussain	Ordinary Portland
Manhole 44 to Manhole 45	4322.6	52.26	Akhtar Hussain	Sulphate Resisting
Manhole 49 to Manhole 50	4815	36.10	Akhtar Hussain	Ordinary Portland
Manhole 54 to Manhole 55	5322.7	19.45	Akhtar Hussain	Ordinary Portland

Table 3.8

Details of Concrete/Plaster Samples & Laboratory Testing

Sample Location (Halcrow Reference)	Chainage (meters)	RD (Feet)	Date of Sampling	Size of Sample (mm)	Type of Test Performed			
					Compressive Strength	Petrographic Examination	Sulphate Soundness	Chemical Analysis
Open Channel	-224.5	201.44	May 13, 1997	600x600x15 thick				•
Box Structure2 to Manhole 1	20.7	193.40	May 09,1997	A:100x83	•	•		
				B: 105x83			•	
				C: 75x83				•
Manhole 9 to Manhole 10	838.3	166.57	May 09,1997	A; 90x83	•			
Manhole 15 to Manhole 16	1411.2	147.78	May 09,1997	A: 60x83	•			
Manhole 20 to Manhole 21	1953.4	129.99	May 12, 1997	A: 50x83	•			
Manhole 27 to Manhole 28	2664	106.67	May 12, 1997	A: 67x83	•	•		
				B: 90x83			•	
				C:85x83				•
Manhole 35 to Manhole 36	3420.7	81.85	May 12, 1997	A: 85x83	•			
Manhole 40 to Manhole 41	3944.7	64.66	May 12, 1997	A: 50x83	•			
				B: 60x83			•	
Manhole 44 to Manhole 45	4322.6	52.26	May 12, 1997	A: 47x83	•			
Manhole 49 to Manhole 50	4815	36.10	May 12, 1997	A: 75x83	•			
Manhole 54 to Manhole 55	5322.7	19.45	May 12, 1997	A: 65x83	•	•		
				B: 60x83			•	
				C: 70x83				•

Table 3.9

pH AND CONDUCTIVITY MEASUREMENTS.

Location	Date	Time (hrs.)	Temperature (oC)	pH	Conductivity (ms)
Pandoki drain, (approx.140 m)	May 11, 1997	17:25	31	8.24	1.82
upstream of outfall location	May 12, 1997	17:30	32.6	8.72	1.78
Pandoki drain, (approx.100 m)	May 11, 1997	17:33	29.6	7.7	3.7
downstream of outfall location	May 12, 1997	17:42	30.6	7.72	4.12
First Box Structure between Manhole17	May 11, 1997	17:47	29	7.52	2.67
Manhole 18	May 12, 1997	17:59	29.4	7.62	3.19
Start of 54" pipeline	May 11, 1997	17:58	28	7.38	2.46
	May 12, 1997	18:13	28.5	7.59	2.98

Table 3.10

HYDROGEN SULPHIDE TESTING

Manhole Location	Chainage (Meters)	H2S Concentration (ppm)
MH09	801.6	42
MH27	2535.5	57
MH 51	4984	55

Table 3.11

DETAILS OF VISUAL INSPECTION

Location	Sulphate Attack	Manhole Cover Concrete Condition	Pipe Concrete and Manhole Interior Condition
MH02	Low	No Spalling	No visible signs of spalling, Iron stairs were in good condition
MH04	Low	No Spalling	No visible signs of spalling, Iron stairs were in good condition
MH06	Low	Low Spalling	No visible signs of spalling, Iron stairs were in good condition
MH09	Medium	No Spalling	Medium spalling of pipe edges
MH11	Medium	Low Spalling	Smooth Pipe Edge
MH13	Medium	Medium Spalling	Smooth Pipe Edge
MH17	Severe	Medium Spalling	Medium spalling of pipe edges
MH20	Medium	Medium Spalling	Medium spalling of pipe edges
MH21	Medium	Medium Spalling	Medium spalling of pipe edges, Seems affected by sulphate attack
MH25	Medium	Low Spalling	Medium Spalling of upstreem Pipe
MH27	Severe	Severe Spalling	Medium spalling of pipe edges, Seems affected by sulphate attack
MH29	Low	No Spalling	High spalling of downstreem pipe
MH33	Medium	No Spalling	No spalling of pipe
MH34	Medium	No Spalling	No spalling of pipe
MH36	Medium	Honeycombing, No Spalling	No spalling of pipe
MH40	Low	Medium Spalling	Low spalling of pipe
MH42	Low	Honeycombing, Severe Spalling	High spalling of pipe
MH44	Medium	Medium Spalling	Medium spalling of pipe
MH48	Medium	Medium Spalling	Low spalling of pipe
MH49	Medium	Medium Spalling	Low spalling of pipe
MH50	Low	Low Spalling	Low spalling of pipe

Table 4.1

COMPRESSIVE STRENGTH TESTING RESULTS

Location	Size of Sample (mm)	Density (g/cm3)	Failure Load (KN)	Mode of Failure	Compressive Strength Cube Size (50 mm)		Corrected Compressive Strength Cube Size (150 mm)	
					PSI	MPa	PSI	MPa
Box Structure 2 to MH 1	100x83	2.398	69.86	All side face failure	4052.99	27.95	3752.76	25.88
MH09 to MH10	90x83	2.384	72.03	Face & body failure	4178.89	28.81	3869.34	26.68
MH15 to MH16	60x83	2.392	51.829	Crushed during load	3006.91	20.73	2784.17	19.20
MH21 to MH22	50x83	2.43	50.057	Two side crack failure	2904.1	20.02	2689.00	18.54
MH27 to MH28	67x83	2.438	73.87	Two side crack failure	4285.64	29.55	3968.18	27.36
MH35 to MH36	85x83	2.421	78.3	Face toppling failure	4542.65	31.32	4206.00	29.00
MH40 to MH41	50x83	2.37	60.89	Crushed during load	3532.59	24.36	3271.00	22.55
MH44 to MH45	47x83	2.429	78.13	Two face failure	4532.79	31.25	4197.00	28.94
MH49 to MH 50	75x83	2.433	58.52	Two face failure	3395.09	23.41	3143.60	21.68
MH54 to MH55	65x83	2.419	82.66	One side face failure	4795.6	33.07	4440.37	30.62

Table 4.2

REPORTED RESULTS OF CHEMICAL ANLYSIS & APPROXIMATE COMPOSITION LIMITS FOR ORDINARY PORTLAND CEMENT

Compounds	Percent by mass in ordinary portland cement					Percent Present in Samples			
	Approximate composition			South African Standard		Open Channel	Box Structure 2 to MH 1	MH27-28	MH54-55
	Lower Limit	Upper Limit	Typical	Lower Limit	Upper Limit	(-224.5)	(20.7)	(2664)	(5322.7)
SO3	1.00	3.00	2.00	2.35	4.10	2	1.03	0.79	0.78
Fe2O3	0.50	6.00	3.00	1.64	3.29	2.56	2.13	6.44	8.73
Al2O3	3.00	8.00	6.00	2.94	6.63	6.9	5.18	10.68	11.9
CaO (Free)				0.50	2.50				
CaO	60.00	67.00	63.00	45.85	81.49	14.64	36.2	12.09	12.37
SiO2	17.00	25.00	20.00	16.16	28.39	65.14	29.22	54.94	53.27
MgO	0.10	4.00	1.50	0.30	4.00	0.88	1.03	2.64	4.35
K2O						1.57	0.68	1.62	0.89
Na2O						0.72	0.47	1.15	1.76
Alkalis (K2O+Na2O)	0.20	1.30	1.00						
Na2O+0.658K2O						1.75	0.92	2.22	2.35
Loss on ignition			2.00			7.23	24.79	9.3	5.29
Cl (ppm)						171	<30	42.06	37.85
Insoluble residue			0.50						
C3A (Using Bogue's Eq.)	7.11	11.06	10.83	5.00	12.00	13.96	10.13	17.42	16.78

Table 4.3

MAGNESIUM SULPHATE SOUNDNESS TEST RESULTS

Location	Size of Sample (mm)	Weight Before Test (g)	Density (g/cm3)	Weight After Test (g)	Weight Loss (%)	Visual Observations
Box Structure 2 to MH1	50	325.9	2.61	325.1	0.25	Slight pin holes after first cycle. Size of pin holes increased after second cycle
MH 27 to MH 28	50	332.7	2.66	330.8	0.57	Slight pin holes after first cycle
MH 40 to MH 41	50	344.7	2.76	343.9	0.23	Slight pin holes after first cycle
MH 54 to MH 55	50	335.9	2.69	335.9	0.00	Slight pin holes after first cycle

Table 4.4

RESULTS OF PETROGRAPHIC MODAL ANALYSIS OF COARSE & FINE AGGREGATE

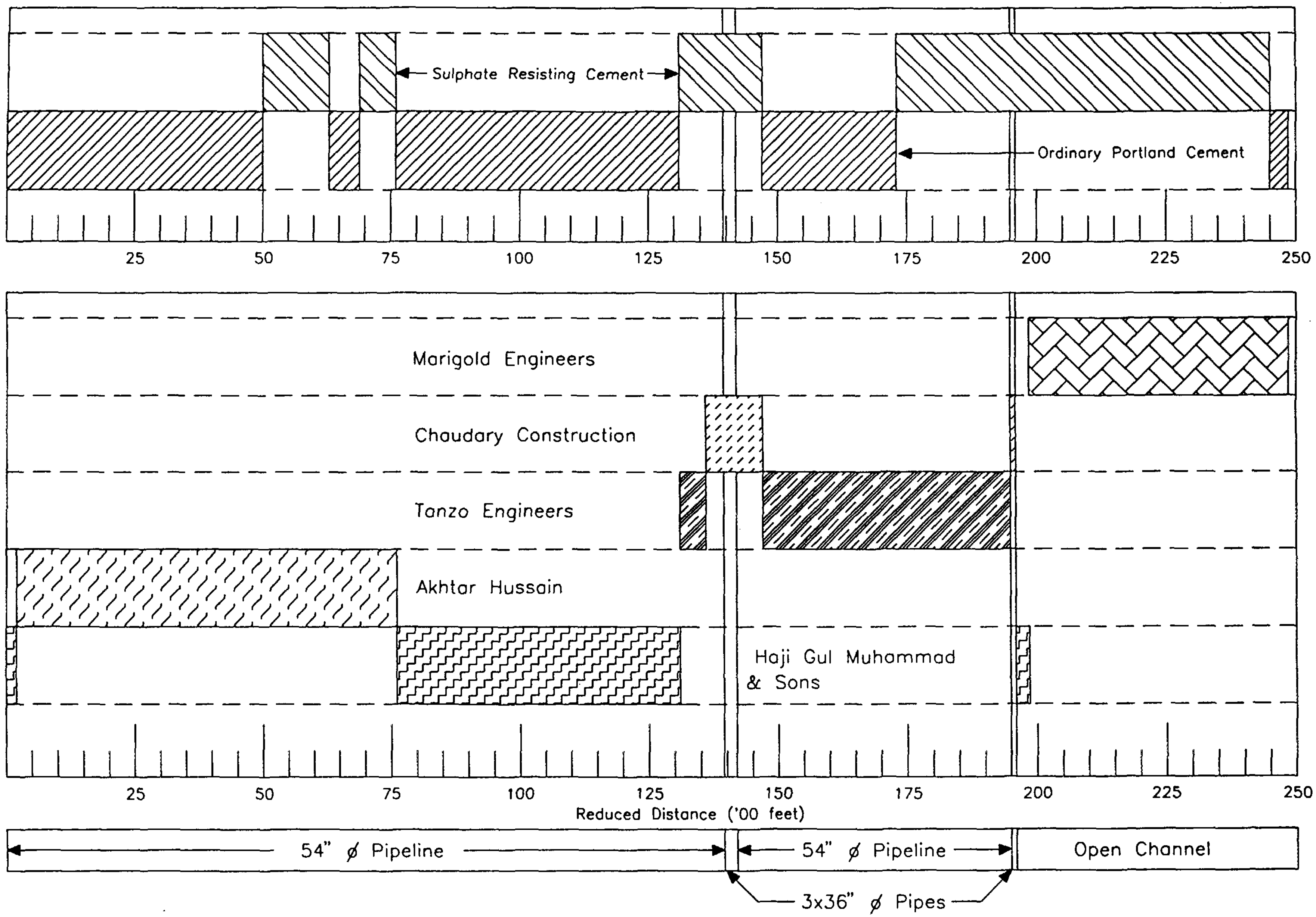
Constituents	Coarse Aggregate			Fine Aggregate		
	Box structure 2 to MH 1	MH 27 to MH 28	MH 54 to MH 55	Box structure 2 to MH 1	MH 27 to MH 28	MH 54 to MH 55
Rock Types						
Quartizite (%)	35.70	28.90	23.70	5.50	16.40	19.00
Quartz Mica Schist (%)				4.40	4.30	4.00
Diorite/Granitoids (%)	4.10	0.60	26.70			
Limestone (%)	3.60	1.00	5.30			
Granite (%)				3.20	3.00	1.70
Greywacke* + Gray microfractured Sandstones (%)	43.90	62.00	30.30	0.40	0.70	0.60
Slate/Phyllite* (%)	0.50	0.40	0.30	1.00	0.70	0.80
Chert* (%)				0.70	0.60	0.50
Acid to Intermediate Volcanics* (%)	12.20	7.10	13.70			
Minerals						
Quartz (%)				53.50	51.90	53.00
Feldspar (%)				5.70	7.10	8.30
Amphibole (%)				8.60	8.70	3.60
Biotite (%)				9.40	1.20	1.80
Muscovite (%)				2.00	1.40	2.20
Magnetite (%)				1.40	1.70	2.00
Epidote (%)				2.80	0.90	1.00
Garnet (%)				0.80	0.80	1.10
Zircon (%)				0.40	0.50	0.30
Tourmaline (%)				0.20	0.10	0.10

* Potential deleterious constituents with an Alkali Silica Reaction (ASR) potential

Table 5.1

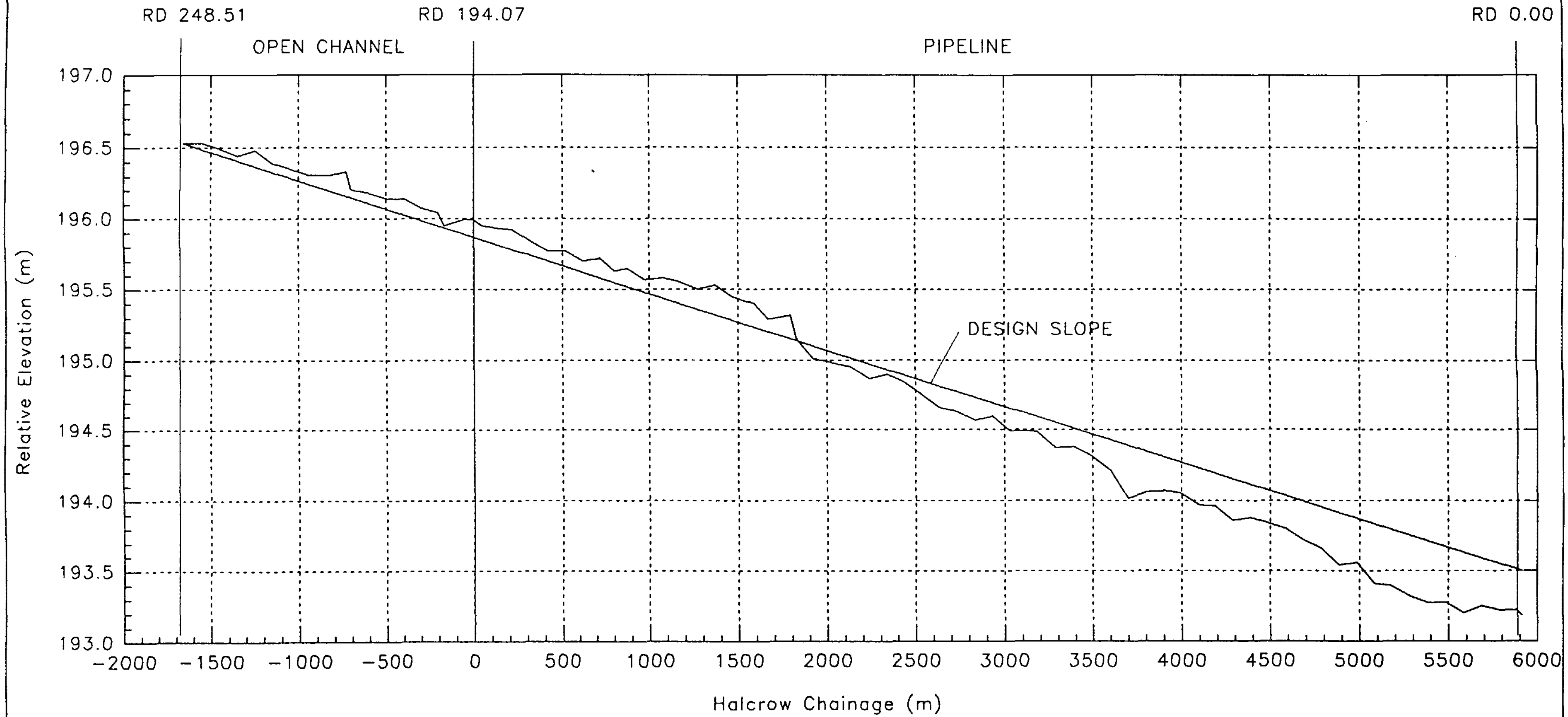
TOTAL LENGTHS OF SECTIONS CONSTRUCTED BY EACH CONTRACTOR

Name of Contractor	Total Length of Sections with OPC/Slag			Total Length of Sections with SRC			Total Length of Sections for Each Contractor		
	(Feet)	(meters)	% of Total	(Feet)	(meters)	% of Total	(Feet)	(meters)	% of Total
Haji Gul Muhammad & Sons	5,660.00	1,725.17	22.78	225	68.58	0.91	5,885.00	1,793.75	23.68
Akhtar Hussain	5,500.76	1,676.63	22.13	1,959.24	597.18	7.88	7,460.00	2,273.81	30.02
Tanzo Engineers	2,600.00	792.48	10.46	2,680.00	816.86	10.78	5,280.00	1,609.34	21.25
Chaudary Construction	0.00	0.00	0.00	1,180.00	359.66	4.75	1,180.00	359.66	4.75
Marigold Engineers	350.00	106.68	1.41	4695	1,431.04	18.89	5,045.00	1,537.72	20.30
Total for each type of Cement	**14,110.76**	**4,300.96**	**56.78**	**10,739.24**	**3,273.32**	**43.21**	**24,850.00**	**7,574.28**	**100.00**



HALCROW

KASUR TANNERIES POLLUTION CONTROL
EVALUATION OF DRAINAGE SYSTEM
CONCRETE WORKS
CONTRACT BOUNDARIES OF CEMENT TYPE
FIGURE 2.1



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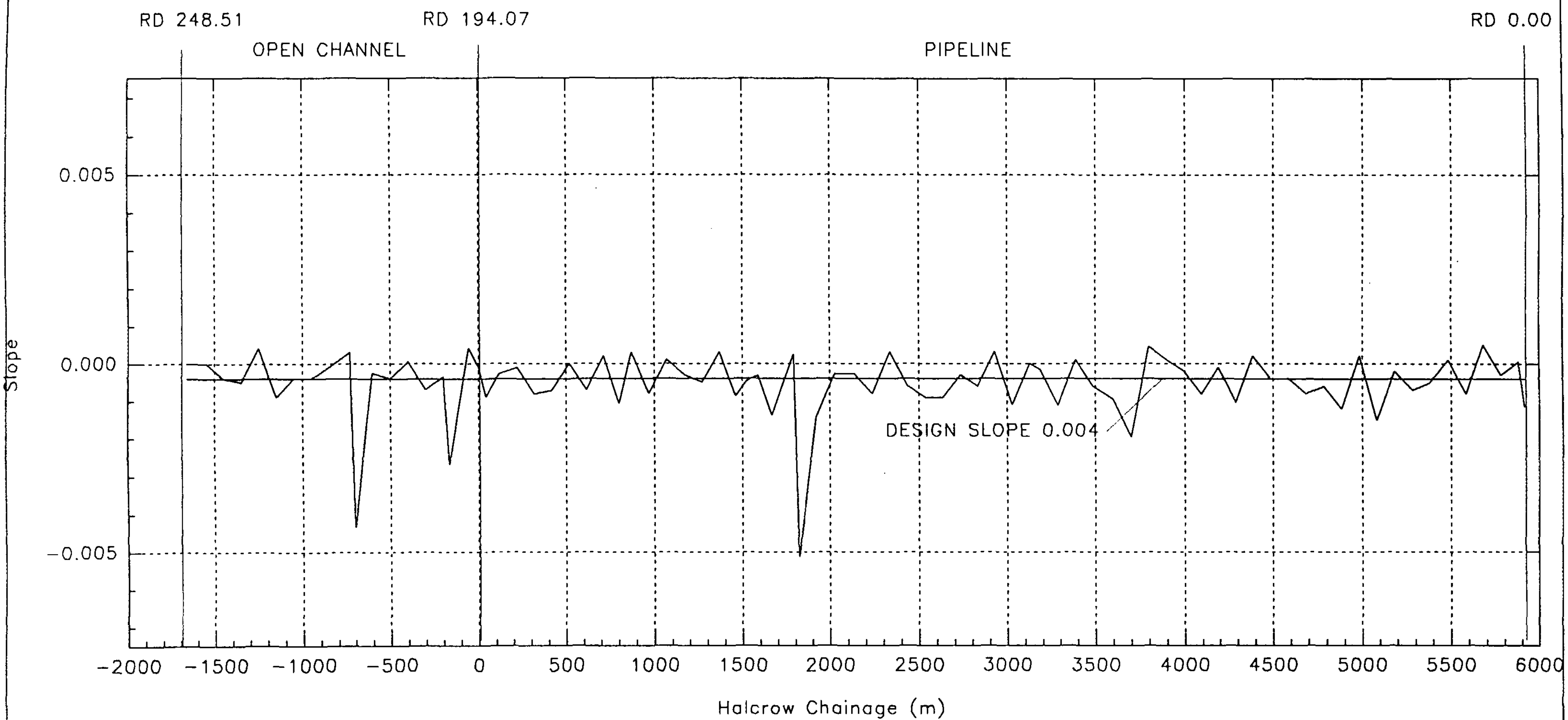
United Nations Industrial Development Organisation
Kasur Tanneries Pollution Control Project DP/PAK/93/006

HYDRAULIC GRADE OF OPEN CHANNEL & PIPELINE

FIG 3.1



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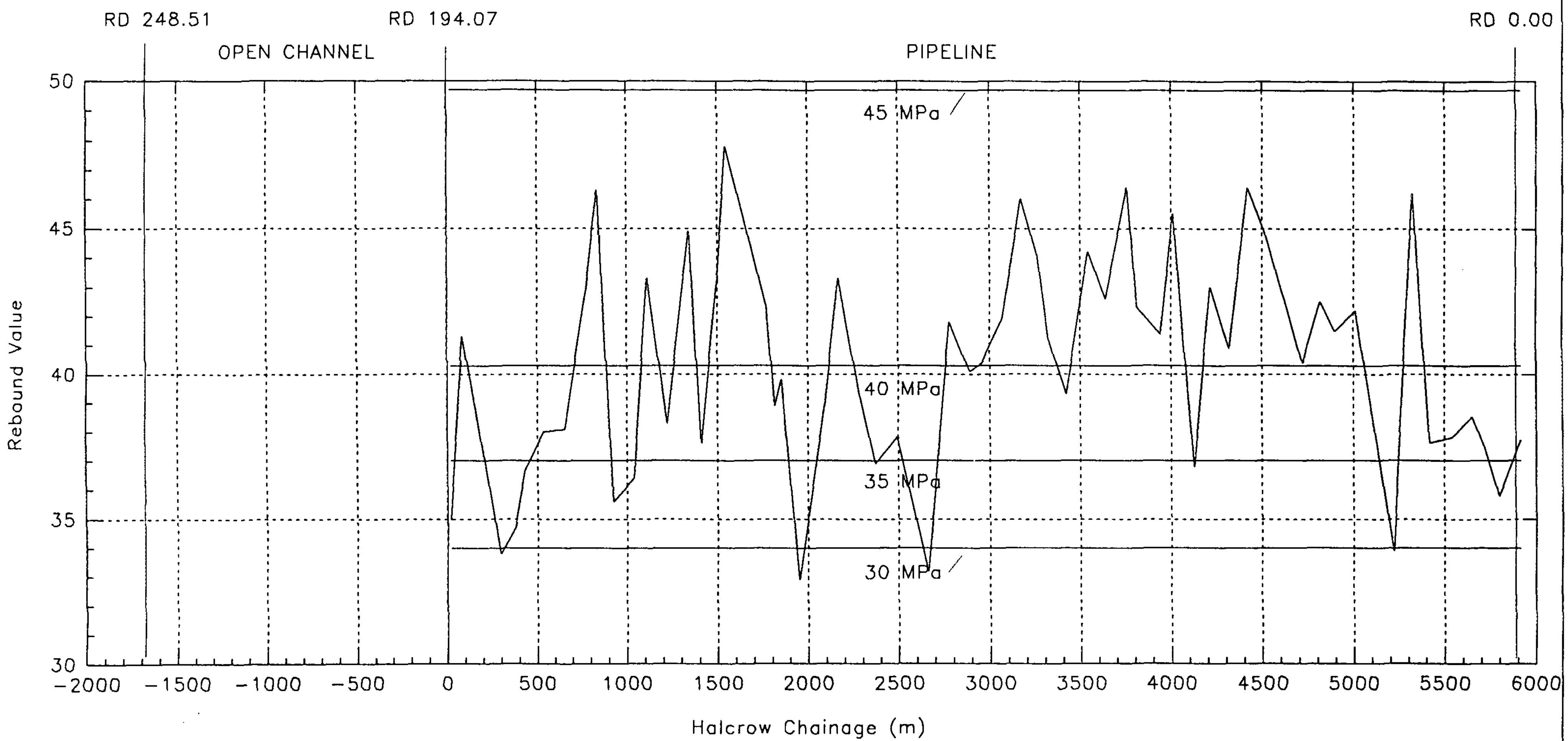
United Nations Industrial Development Organisation
Kasur Tanneries Pollution Control Project DP/PAK/93/006

DEVIATION OF SLOPE FROM DESIGN SLOPE

FIG 3.2



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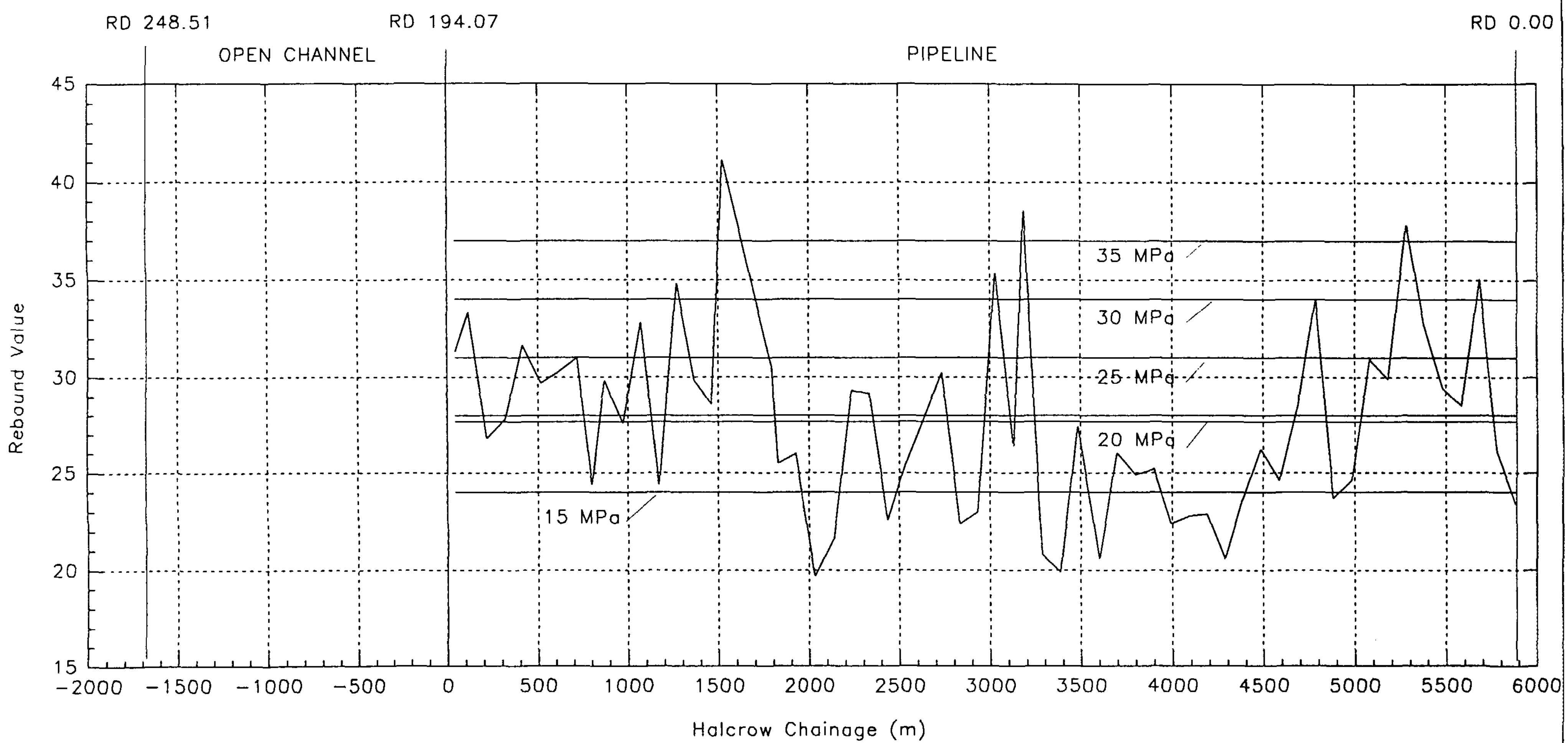
Kasur Tanneries Pollution Control Project DP/PAK/93/006

NON–DESTRUCTIVE TEST RESULTS – PIPELINE

FIG 3.3



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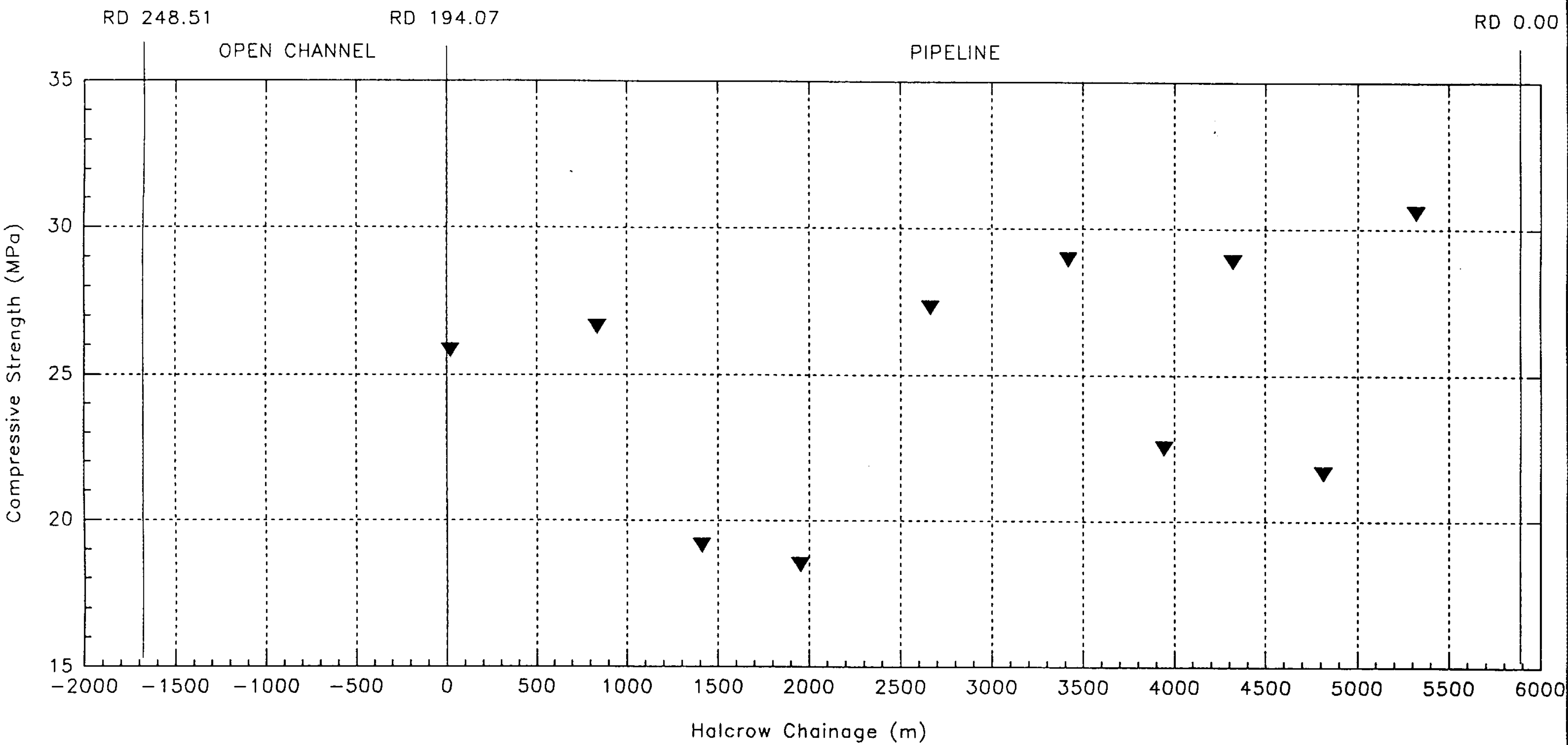
Kasur Tanneries Pollution Control Project DP/PAK/93/006

NON-DESTRUCTIVE TEST RESULTS – MANHOLE COVERS

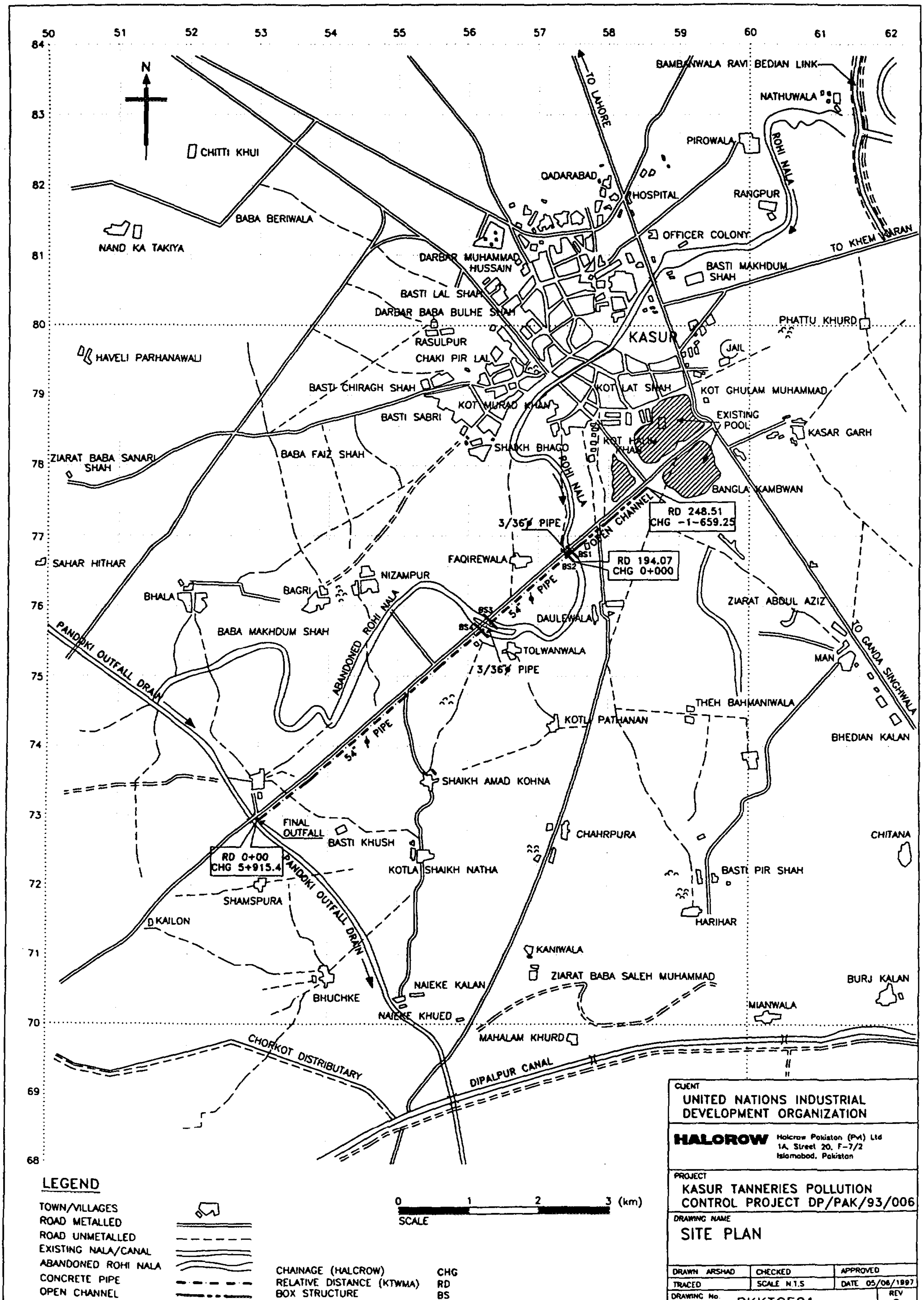
FIG 3.4

HALCROW

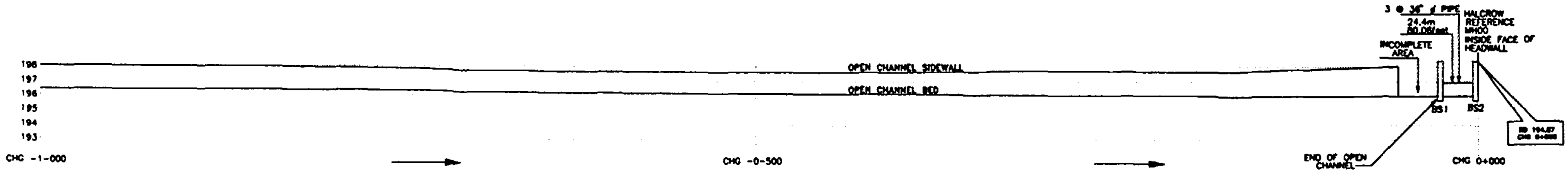


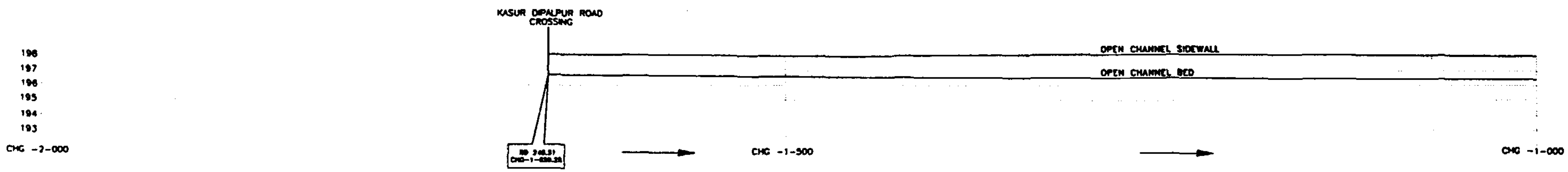
HALCROW

United Nations Industrial Development Organisation
Kasur Tanneries Pollution Control Project DP/PAK/93/006
COMPRESSIVE STRENGTH TESTS – PIPELINE
FIG 4.1



N
CHITTI KHUI
NAND KA TAKIYA
BABA BERIWALA
HAVELI PARHANAWALI
ZIARAT BABA SANARI SHAH
SAHAR HITHAR
BHALA
BAGRI
NIZAMPUR
BABA MAKHDUM SHAH
ABANDONED ROHI NALA
PANDOKI OUTFALL DRAIN
BABA FAIZ SHAH
BASTI CHIRAGH SHAH
BASTI SABRI
KOT MURAD KHAN
SHAIKH BHAGO
DARBAR MUHAMMAD HUSSAIN
BASTI LAL SHAH
DARBAR BABA BULHE SHAH
RASULPUR
CHAKI PIR LAL
TO LAHORE
QADARABAD
HOSPITAL
PIROWALA
BAMBANWALA RAVI BEDIAN LINK
NATHUWALA
ROHI NALA
RANGPUR
OFFICER COLONY
TO KHEM KARAN
BASTI MAKHDUM SHAH
PHATTU KHURD
KASUR
JAIL
KOT LAT SHAH
KOT GHULAM MUHAMMAD
EXISTING POOL
KASAR GARH
KOT HALIM KHAN
BANGLA KAMBWAN
OPEN CHANNEL
RD 248.51
CHG -1-659.25
RD 194.07
CHG 0+000
3/36" PIPE
FAQIREWALA
BS1
BS2
BS3
BS4
54" PIPE
DAULEWALA
TOLWANWALA
ZIARAT ABDUL AZIZ
TO GANDA SINGHWALA
MAN
THEH BAHMANIWALA
KOTLI PATHANAN
BHEDIAN KALAN
SHAIKH AMAD KOHNA
FINAL OUTFALL
BASTI KHUSH
RD 0+00
CHG 5+915.4
KOTLA SHAIKH NATHA
CHAHRPURA
CHITANA
BASTI PIR SHAH
HARIHAR
SHAMSPURA
KAILON
KANIWALA
ZIARAT BABA SALEH MUHAMMAD
BURJ KALAN
BHUCHKE
NAIEKE KALAN
NAIEKE KHUED
MIANWALA
MAHALAM KHURD
CHORKOT DISTRIBUTARY
DIPALPUR CANAL
50 51 52 53 54 55 56 57 58 59 60 61 62
84 83 82 81 80 79 78 77 76 75 74 73 72 71 70 69 68
LEGEND
TOWN/VILLAGES
ROAD METALLED
ROAD UNMETALLED
EXISTING NALA/CANAL
ABANDONED ROHI NALA
CONCRETE PIPE
OPEN CHANNEL
CHAINAGE (HALCROW) CHG
RELATIVE DISTANCE (KTWMA) RD
BOX STRUCTURE BS
0 1 2 3 (km)
SCALE
CLIENT
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
HALCROW
Halcrow Pakistan (Pvt) Ltd
1A, Street 20, F-7/2
Islamabad, Pakistan
PROJECT
KASUR TANNERIES POLLUTION CONTROL PROJECT DP/PAK/93/006
DRAWING NAME
SITE PLAN
DRAWN ARSHAD
CHECKED
APPROVED
TRACED
SCALE N.T.S
DATE 05/06/1997
DRAWING No.
PKKTCE01
REV
0





LEGEND

MH:	MANHOLE
BS:	BOX STRUCTURE
CHG:	CHAINAGE, METRES (HALCROW) FOR EQUIVALENT RELATIVE DISTANCES. SEE TABLE No.3.2 & 3.3
RD:	RELATIVE DISTANCE 100 FEET (KTWMA)

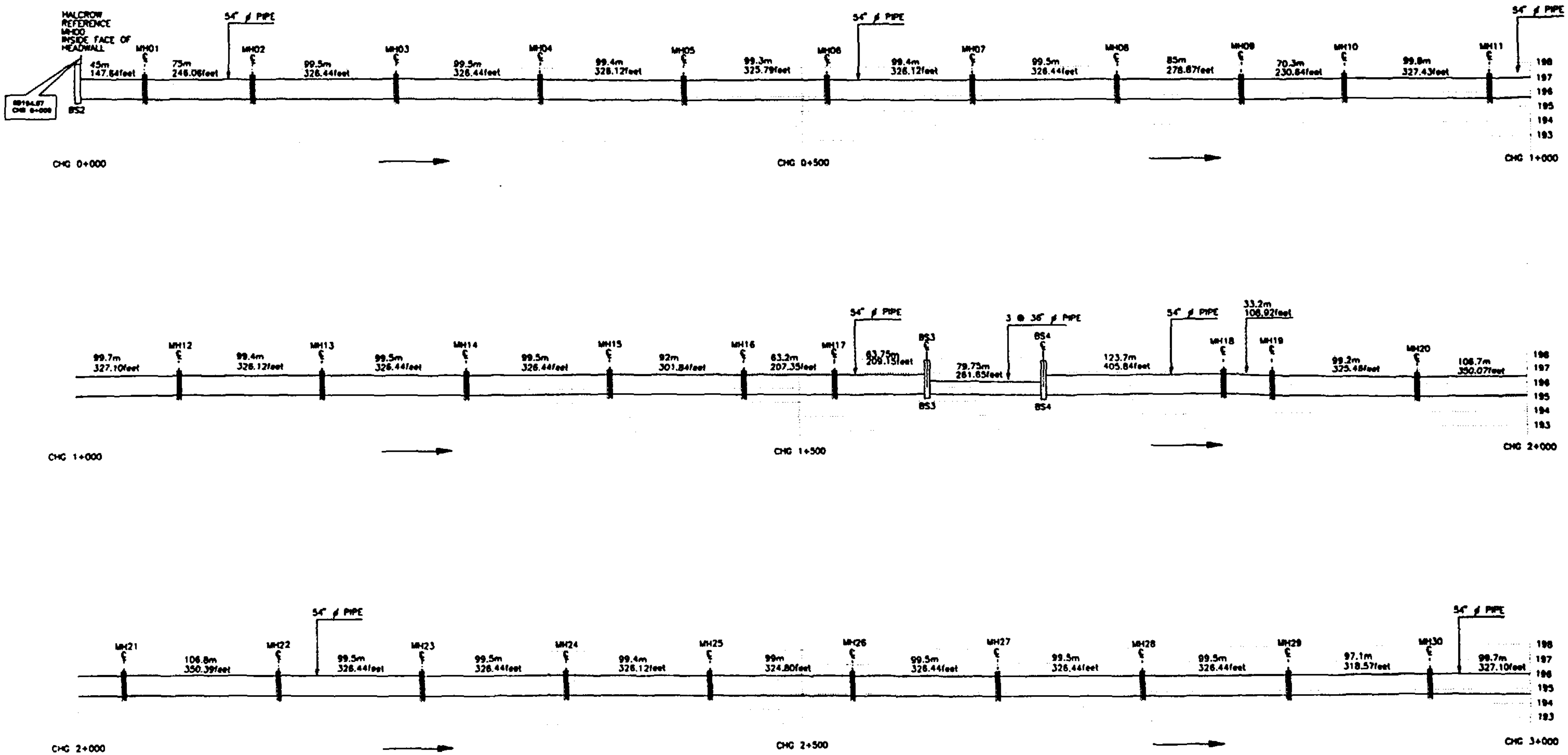
CLIENT
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

HALCROW
Halcrow Pakistan (PVT) Ltd
House 1A,Street 20
F-7/2, Islamabad
Pakistan

PROJECT
KASUR TANNERIES POLLUTION CONTROL PROJECT DP/PAK/93/006

MAP:
DRAINAGE SYSTEM SECTIONS
SHEET 1 OF 3

DRAWN ARSHAD	CHECKED	APPROVED
TRACED	SCALE 1:4000	DATE 03/06/1997
DRAWING No. PKKTCE02		REV 0



LEGEND

MH: MANHOLE

BS: BOX STRUCTURE

CHG: CHAINAGE,METRES (HALCROW) FOR EQUIVALENT RELATIVE DISTANCES. SEE TABLE No.3.2 & 3.3

RD: RELATIVE DISTANCE 100 FEET (KTWMA)

CLIENT
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

HALCROW

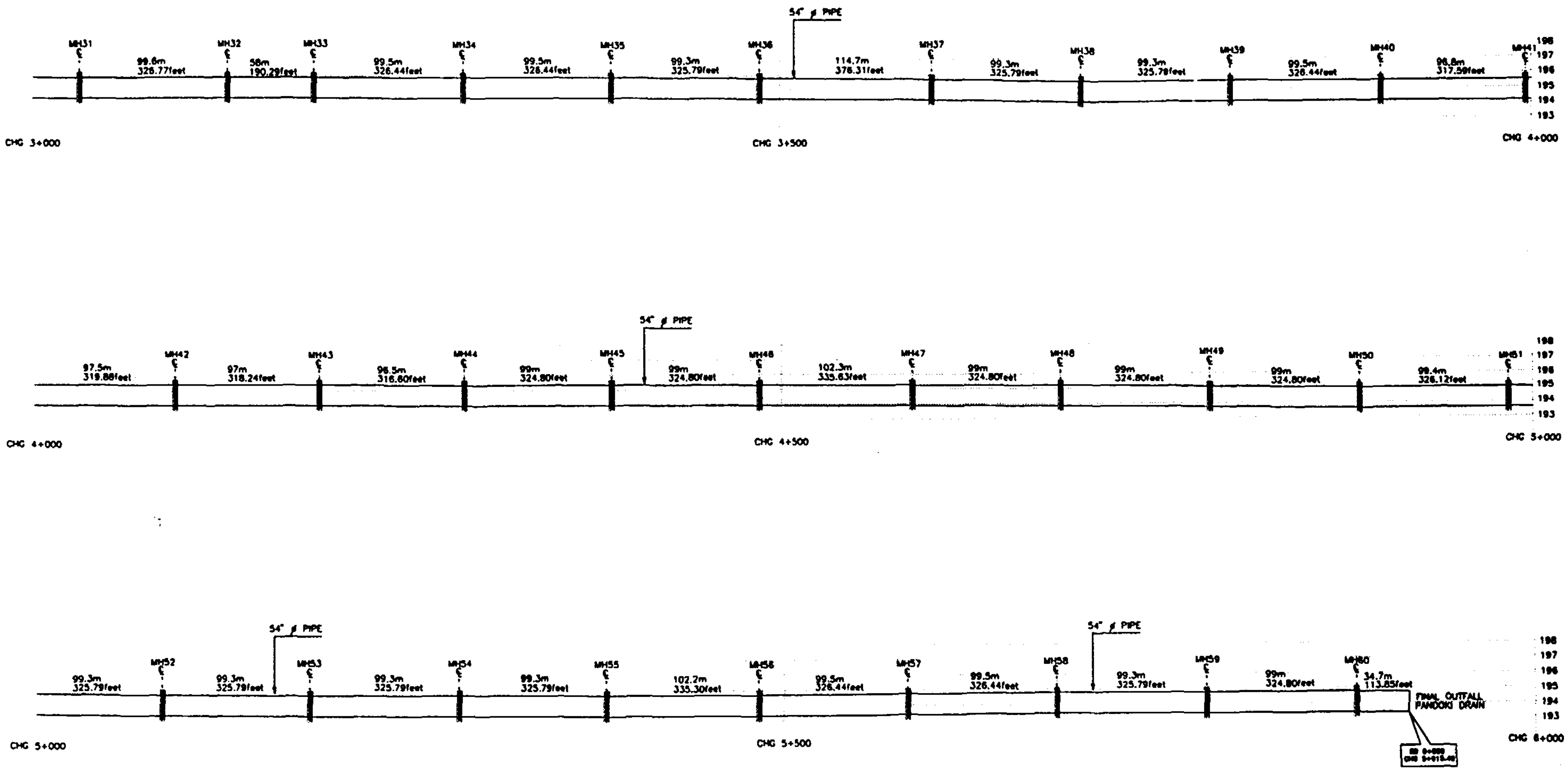
Halcrow Pakistan (PVT) Ltd
House 1A,Street 20
F-7/2, Islamabad
Pakistan

PROJECT
KASUR TANNERIES POLLUTION CONTROL PROJECT DP/PAK/93/006

MAP:
DRAINAGE SYSTEM SECTIONS SHEET 2 OF 3

DRAWN ARSHAD	CHECKED	APPROVED
TRACED	SCALE 1:4000	DATE 03/06/1997

DRAWING No. PKKTCE02 REV 0



LEGEND

MH:	MANHOLE
BS:	BOX STRUCTURE
CHG:	CHAINAGE, METRES (HALCROW) FOR EQUIVALENT RELATIVE DISTANCES, SEE TABLE No.3.2 & 3.3
RD:	RELATIVE DISTANCE 100 FEET (KTWMA)

CLIENT
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

HALCROW
Halcrow Pakistan (PVT) Ltd
House 1A, Street 20
F-7/2, Islamabad
Pakistan

PROJECT
KASUR TANNERIES POLLUTION CONTROL PROJECT DP/PAK/93/006

MAP:
DRAINAGE SYSTEM SECTIONS SHEET 3 OF 3

DRAWN ARSHAD	CHECKED	APPROVED
TRACED	SCALE 1:4000	DATE 03/06/1997
DRAWING No. PKKTCE02		REV 0

REPORT

Three samples were provided by Mr. Naveed Ahmed Halcrow Pakistan (Pvt) Ltd.,House 1A, Street 20, F-7 / 2 Islamabad,Pakistan, vide letter Ref.No. PKKTCE001, dated 26 May, 1997.

The samples had following location identification.

1. 1A
2. 5A
3. 10A

The samples provided were studied as follows.

1. Megascopically.
2. Under low magnification.
3. Small pieces were studied under stereomicroscope.
4. In thin sections and grain mounts under petrographic microscope.
5. The fine fraction was extracted and grain counted.
6. Total quantitative modal analysis were carried out on coarse as well as fine parts.
7. Rock and mineral types in all the samples were identified.

The results are given in Tables 1,2,3,4,5,6 and 7.

The deleterious constituents are marked with an "ASTERISK*.

The potentially deleterious rock types include, greywacke, acid to intermediate volcanics, and slate/phyllite.

Muhammad Nawaz

Professor,
Institute of Geology
University of the Punjab,
LAHORE.

The concrete cores were studied megascopically, under low magnification. Six thin sections were also prepared in order to study deterioration in the cement paste at microscopic scale.

The deleterious reactions in the concrete were studied in detail both in the cores and in the thin section. The results are as follows:-

1. There is a distinct though minor deterioration due to dissolution and leaching of cement paste.
2. The carbonate fragment both in sand and coarser aggregate are etched and dissolved. They show dissolution and leaching. But deterioration is minor.
3. It appears that the cores provided have been subjected to aggressive fluids with acidic and oxidising properties.
4. Due to such acidic environments the Alkali Silica Reactions which would have taken place to a certain degree (considering the composition of the coarse aggregate) have either been suppressed or if such a reaction had at all taken places the products of reaction have also been removed through leaching.
5. The reactions are manifest on exposed surfaces and along microfractures, cracks and discontinuities.
6. Chlorides and sulphates are present only in traces.
7. Secondary carbonates are present only in traces.
8. Secondary iron oxides are present.

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CONCLUSION

Dissolution and leaching of the cement paste and of carbonates has taken place. Such effects are manifest on surfaces and along fractures, pores and other discontinuities. In the cores provided the reactions and therefore damage, as a whole is minor.

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Institute of Geology
University of the Punjab
LAHORE

TOTAL AVERAGE OF THREE SAMPLES (COARSE FRACTION)

Greywacke*+Gray microfractured sandstones	45.4%
Quartzite	29.4%
Acid to Intermediate Volcanics*	11.0%
Diorite/Granitoids	10.5%
Limestone	3.3%
Slate/Phyllite*	0.4%

***Potentially Deleterious Constituents with an ASR Potential.**

Note: Due to the small sample size the results are only semi quantitative for the coarse fraction.

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TABLE NO.1

PETROGRAPHIC MODAL ANALYSIS OF COARSE AGGREGATE

Sample No. 13019 (1A)

Greywacke*+Gray microfractured sandstones	43.9%
Quartzite	35.7%
Acid to Intermediate Volcanics*	12.2%
Diorite/Granitoids	4.1%
Limestone	3.6%
Slate/Phyllite*	0.5%

***Potentially Deleterious Constituents with an ASR Potential**

Note: Due to the small sample size the results are only semi quantitative for the coarse fraction.

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TABLE NO.2

PETROGRAPHIC MODAL ANALYSIS OF COARSE AGGREGATE

Sample No. 13024 (5A)

Greywacke*+Gray microfractured sandstones	62.0%
Quartzite	28.9%
Acid to Intermediate Volcanics*	7.1%
Limestone	1.0%
Diorite/Granitoids	0.6%
Slate/Phyllite*	0.4%

***Potentially Deleterious Constituents with an ASR Potential**

Note: Due to the small sample size the results are only semi quantitative for the coarse fraction.

Muhammad Nawaz

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LAHORE

TABLE NO.3

PETROGRAPHIC MODAL ANALYSIS OF COARSE AGGREGATE

Sample No. 13031 (10A)

Greywacke*+Gray microfractured sandstones	30.3%
Diorite/Granitoids	26.7%
Quartzite	23.7%
Acid to Intermediate Volcanics*	13.7%
Limestone	5.3%
Slate/Phyllite*	0.3%

***Potentially Deleterious Constituents with an ASR Potential.**

Note: **Due to the small sample size the results are only semi quantitative for the coarse fraction.**

Muhammad Nawaz

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LAHORE

TABLE NO.4

PETROGRAPHIC MODEL ANALYSIS OF FINE AGGREGATE (AVERAGE)

Quartz	53.0%
Quartzite	13.6%
Feldspar	7.0%
Amphibole	6.9%
Quartz Mica Schist	4.2%
Biotite	4.1%
Granite	2.6%
Muscovite	1.9%
Magnetite	1.7%
Epidote	1.6%
Garnet	0.9%
Slate/Phyllite*	0.8%
Chert*	0.6%
Greywacke*	0.6%
Zircon	0.4%
Tourmaline	0.1%

***Potentially deleterious constituents with an ASR Potential.**

Note: Due to the fine grain size of the sand the results are quantitative.

Muhammad Nawaz

Professor
Institute of Geology
University of the Punjab
LAHORE

TABLE NO.5

PETROGRAPHIC MODEL ANALYSIS OF FINE AGGREGATE

Sample No.13019 (1A)

Quartz	53.5%
Biotite	9.4%
Quartz Mica Schist	4.4%
Amphibole	8.6%
Feldspar	5.7%
Quartzite	5.5%
Granite	3.2%
Epidote	2.8%
Muscovite	2.0%
Magnetite	1.4%
Slate/Phyllite*	1.0%
Garnet	0.8%
Chert*	0.7%
Greywacke*	0.4%
Zircon	0.4%
Tourmaline	0.2%

***Potentially deleterious constituents with an ASR Potential**

Note: Due to the fine grain size of the sand the results are quantitative.

Muhammad Na

Professor,
Institute of Geology
University of the Punjab
LAHORE

TABLE NO.6

PETROGRAPHIC MODEL ANALYSIS OF FINE AGGREGATE

Sample No.13024(5A)

Quartz	51.9%
Quartzite	16.4%
Amphibole	8.7%
Feldspar	7.1%
Quartz Mica Schist	4.3%
Granite	3.0%
Magnetite	1.7%
Muscovite	1.4%
Biotite	1.2%
Epidote	0.9%
Garnet	0.8%
Slate/Phyllite*	0.7%
Greywacke*	0.7%
Chert*	0.6%
Zircon	0.5%
Tourmaline	0.1%

***Potentially deleterious constituents with an ASR Potential**

Note: Due to the fine grain size of the sand the results are quantitative. Muhammad N.

Professor,
Institute of Geology,
University of the Punjab
LAHORE

TABLE NO.7

PETROGRAPHIC MODEL ANALYSIS OF FINE AGGREGATE

Sample No.13031 (10A)

Quartz	53.0%
Quartzite	19.0%
Feldspar	8.3%
Quartz Mica Schist	4.0%
Amphibole	3.6%
Muscovite	2.2%
Magnetite	2.0%
Biotite	1.8%
Granite	1.7%
Garnet	1.1%
Epidote	1.0%
Slate/Phyllite*	0.8%
Greywacke*	0.6%
Chert*	0.5%
Zircon	0.3%
Tourmaline	0.1%

***Potentially deleterious constituents with an ASR Potential**

Note: Due to the fine grain size of the sand the results are quantitative. Muhammad Na

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Appendix D
Laboratory Testing Results

HALCROW

Geoscience Laboratory
Geological Survey of Pakistan
Government of Pakistan
Shahzad TownP.O. Box. 1461, ID
Phone: 240173, 240423-25
Telex: 054663 GSLID PK
Fax: 240223

To: **Mr.Naveed Ahmed.**
Environmental Engineer.
HALCROW PAKISTAN (pvt) Ltd.
ISLAMABAD.

Date: 26-05-97

Major elements (Wt %)

Sample name	**NA-1**	**MHD-1**	**MH 27-28**	**MH 54-55**
SiO_2	65.14	29.22	54.94	53.27
TiO_2	0.267	0.218	0.903	1.167
Al_2O_3	6.90	5.18	10.68	11.90
Fe_2O_3	2.56	2.13	6.44	8.73
MnO	0.052	0.048	0.123	0.150
MgO	0.88	1.03	2.64	4.35
CaO	14.64	36.20	12.09	12.37
Na_2O	0.72	0.47	1.15	1.76
K_2O	1.57	0.68	1.62	0.89
P_2O_5	0.059	0.036	0.118	0.137
SO_3	2	1.03	0.79	0.78
Cl (ppm)	171	BDL	42.06	37.85
LOI	7.23	24.79	9.30	5.29

Remarks:

(1) Samples received as pulp.
(2) Analysis carried out on XRF for all the requested major elements using glass bead (FP Method).
(3) SO3 &Cl by press pellet method.
(4) LOI at 1000^{o}C.
(5) BDL means below detection limit; BDL for Cl is 30 ppm.

Analysis by: Chemical Section

CENTRAL MATERIAL TESTING LABORATORY -WAPDA LAHORE.

Ref:- (Related information about cube crushing strength)

CLIENT:- HALCROW CONSULTANTS, ISLAMABAD.
FAX No. +92-51-273157/260 913

PROJECT:- KASUR TANNERIES POLLUTION CONTROL PROJECT KASUR.

Main Hole No.	Density (gm/cm^3)	Mode of Failure
MH 0-1	2.398	All side face failure.
MH 9-10	2.384	Face and bodyfailure
MH 15-16	2.392	Crushed during load.
MH 21-22	2.430	Two side crack failure.
MH 27-28	2.438	Two side crack failure.
MH 35-36	2.421	Face toppling failure.
MH 40-41	2.370	Crushed during load.
MH 44-45	2.429	Two face failure.
MH 49-50	2.433	Two face failure.
MH 54-55	2.419	One side face failure.

Tested by: Sabir Hussain
ARO

Checked by:-
DD - CMTL

ATTN: [illegible]

[illegible] 051/27 3157

CMTL-WAPDA, LAHORE

(Rock Mechanics Laboratory)

Compression Strength Tests

PROJECT: KASUR TANNERIES POLLUTION CONTROL PROJECT.
CLIENT: HALCROW Consultants Islamabad Pakistan.
Tested by: Sabir Hussain
Date:- 20/[illegible].97 Lab. No. 13019 to 13031

Location M?!	Failure Load (KN)	Compressive Strength PSI Cube Size (50 mm)	Corrected Strength PSI For Cube Size (150 mm)
0 to 1	69.85	4052.99	3752.76
09 to 10	72.03	4178.89	3869.34
15 to 16	51.829	3006.91	2784.17
21 to 22	50.057	2904.10	2689
27 to 28	73.87	4285.64	3968.18
35 to 36	78.30	4542.65	4206
40 to 41	60.89	3532.59	3271
44 to 45	78.13	4532.79	4197
49 to 50	58.52	3395.09	3143.6
54 to 55	82.66	4795.60	4440.37

NOTE: The cube samples were submerged in lime-saturated water for 48 hours prior the compression tests.

The strength worked out for small size cube i.e 50x50 mm has been corrected for standard

Checked
30.05.97
Masood Idris
Geologist
CMTL
WAPDA, LAHORE

Appendix A
Three Edge Bearing Test Results

HALCROW

PAKISTAN

WATER AND POWER DEVELOPMENT AUTHORITY

REPORT ON MAGNESIUM SULPHATE SOUNDNESS TEST ON DRILLED CORE SAMPLES FROM STRUCTURE FOR M/S HALCROW PAKISTAN (Pvt) Ltd. FOR THEIR PROJECT KASUR TANNERIES POLLUTION CONTROL.

CENTRAL MATERIAL TESTING LABORATORY, WAPDA

OFF RIAWIND ROAD ,LAHORE-53700

PAKISTAN

WATER AND POWER DEVELOPMENT AUTHORITY

CENTRAL MATERIAL TESTING LABORATORY

2 Km Off Riawind Road, Lahore.

REPORT ON MAGNESIUM SULPHATE SOUNDNESS TEST

FOR

M/S HALCROW PAKISTAN (Pvt) LIMITED

M/s Halcrow Pakistan (Pvt) Ltd.vide their letter No.PKKTCE/109 dated 04.04.97 has desired Central Material Testing Laboratory WAPDA,Lahore to test the drilled core samples from structur at their Project Kasur Tenneries Pollution Control.

Material Supplied.

The following Materials was supplied.

1) Four samples of drilled cores

Four samples of drilled cores taken from KASUR TANNERIES POLLUTION CONTROL PROJECT for MAGNESIUM SULPHATE SOUNDNESS TEST supplied by M/S HALCROW PAKISTAN (Pvt) Ltd. vide their Letter No.PKKTCE/109 dated 04-04-97.

The cores were reshaped into 50mm cubes and test was performed in accordance with ASTM C-88-76 (Modification supplied by the client vide their letter No.PKKTCE/ 001 dated 26-05-97.

Magnesium sulphate solution was prepared as per ASTM C-88. Density of solution was checked and maintained after every cycle between 1.295 to 1.308.

The weights of the cubes were recorded before and after the completion of the tests were recorded.

The initial observations were not ɜd as below.

Cube No.13020

The bottom edge of side 2-4 & 4-2 were already broken during cutting/shaping the cube.

Cube No.13025

Bottom edges of the sides 1-4 , 4-2 & 2-3were already broken during cutting/shaping the cubes.One piece of steel bar is also found in this cube.

Cube No.13028

The bottom edge of side 4 was already broken during cutting/shaping the cube.

Cube No.13032

The bottom edge of side 2-4 & 2-3 were already broken during cutting/shaping the cube. Seven cycles were performed and after completion of every cycle observations were recorded as below.

1- After the completion of 1st. cycle slight pin holes were seen at top side of all four cubes may be by the removal of some dusty particles.

2- After the completion of 2nd. cycle no further significant change was seen in the cubes except cube No. 13020 which shows slight increase in pin holes at sides 2,3 & 4.

3- After the completion of 3rd. cycle no further significant changes were noted in all four cubes.

4- After the completion of 4th. cycle no further significant changes were noted in all four cubes.

5- After the completion of 5th. cycle no further significant changes were noted in all four cubes.

6- After the completion of 6th. cycle no further significant changes were noted in all four cubes.

7- After the completion of 7th. cycle no further significant changes were noted in all four cubes.

The Cubes were washed with the Barium Chloride and then oven dried. The final weights were taken at room temperature.

TEST RESULTS

ON 50 mm CUBES
FOR
MAGNESIUM SULPHATE SOUNDNESS TEST

Sr. No.	Sample No.	Lab. No.	Location	Wt. Before Test(g)	Wt. After Test (g)	% Loss
1	1C	13020	MH 0-1	325.9	325.1	0.25
2	5B	13025	MH 27-28	332.7	330.8	0.57
3	7B	13028	MH 40-41	344.7	343.9	0.23
4	10B	13032	MH 54-55	335.9	335.9	0.09

Photographs are attached herewith at annex -A

Appendix B
Magnesium Sulphate Soundness Tests

HALCROW

Designation: C 88 - 76

An American National Standard

Standard Test Method for
SOUNDNESS OF AGGREGATES BY USE OF SODIUM SULFATE OR MAGNESIUM SULFATE[1]

This standard is issued under the fixed designation C 88; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This method has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This method covers the testing of aggregates to determine their resistance to disintegration by saturated solutions of sodium sulfate or magnesium sulfate. It furnishes information helpful in judging the soundness of aggregates subject to weathering action, particularly when adequate information is not available from service records of the material exposed to actual weathering conditions. Attention is called to the fact that test results by the use of the two salts differ considerably and care must be exercised in fixing proper limits in any specifications which may include requirements for these tests.

NOTE 1—The values stated in the inch-pound units are to be regarded as the standard.

2. Applicable Documents

2.1 *ASTM Standards:*

C 670 Practice for Preparing Precision Statements for Test Methods for Construction Materials[2,4]

E 11 Specification for Wire Cloth Sieves for Testing Purposes[2,3,4]

E 100 Specification for ASTM Hydrometers[3]

E 323 Specification for Perforated-Plate Sieves for Testing Purposes[4]

3. Apparatus

3.1 *Sieves*—with square openings of the following sizes conforming to Specifications E 11 or Specification E 323, for sieving the samples in accordance with Sections 5, 6, and 8:

Fine Series	Coarse Series
No. 100 (150-μm)	5/16 in. (8.0 mm)
	3/8 in. (9.5 mm)
No. 50 (300-μm)	1/2 in. (12.5 mm)
	5/8 in. (16.0 mm)
No. 30 (600-μm)	3/4 in. (19.0 mm)
	1 in. (25.0 mm)
No. 16 (1.18-mm)	1 1/4 in. (31.5 mm)
No. 8 (2.36-mm)	1 1/2 in. (37.5 mm)
	2 in. (50 mm)
No. 5 (4.00-mm)	2 1/2 in. (63 mm)
No. 4 (4.75-mm)	larger sizes by 1/2-in. spread

3.2 *Containers*—Containers for immersing the samples of aggregate in the solution in accordance with the procedure described in this method, shall be perforated in such manner as to permit free access of the solution to the sample and drainage of the solution from the sample without loss of aggregate.

NOTE 2—Baskets made of suitable wire mesh or sieves with suitable openings are satisfactory containers for the samples.

3.3 *Temperature Regulation*—Suitable means for regulating the temperature of the samples during immersion in the sodium sulfate or magnesium sulfate solution shall be provided.

---

[1] This method is under the jurisdiction of ASTM Committee C-9 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.03 on Methods of Testing and Specifications for Physical Characteristics of Concrete Aggregates.

Current edition approved Sept. 24, 1976. Published November 1976. Originally published as C 88 - 31 T. Last previous edition C 88 - 73.

[2] *Annual Book of ASTM Standards*, Part 15.

[3] *Annual Book of ASTM Standards*, Part 41.

[4] *Annual Book of ASTM Standards*, Part 14.

3.4 *Balances*—For fine aggregate, a balance or scale accurate within 0.1 g over the range required for this test; for coarse aggregate, a balance or scale accurate within 0.1 percent or 1 g, whichever is greater, over the range required for this test.

3.5 *Drying Oven*—The oven shall be capable of being heated continuously at 230 ± 9 F (110 ± 5 C) and the rate of evaporation, at this range of temperature, shall be at least 25 g/h for 4 h, during which period the doors of the oven shall be kept closed. This rate shall be determined by the loss of water from 1-liter Griffin low-form beakers, each initially containing 500 g of water at a temperature of 70 ± 3 F (21 ± 2 C), placed at each corner and the center of each shelf of the oven. The evaporation requirement is to apply to all test locations when the oven is empty except for the beakers of water.

3.6 *Specific Gravity Measurement*—Hydrometers conforming to the requirements of Specification E 100, or a suitable combination of graduated glassware and balance, capable of measuring the solution specific gravity within ±0.001.

4. Special Solutions Required

4.1 Prepare the solution for immersion of test samples from either sodium or magnesium sulfate in accordance with 4.1.1 or 4.1.2 (Note 3). The volume of the solution shall be at least five times the solid volume of all samples immersed at any one time.

NOTE 3—Some aggregates containing carbonates of calcium or magnesium are attacked chemically by fresh sulfate solution, resulting in erroneously high measured losses. If this condition is encountered or is suspected, repeat the test using a filtered solution that has been used previously to test the same type of carbonate rock, provided that the solution meets the requirements of 4.1 and 4.2 for specific gravity.

4.1.1 *Sodium Sulfate Solution*—Prepare a saturated solution of sodium sulfate by dissolving a USP or equal grade of the salt in water at a temperature of 77 to 86 F (25 to 30 C). Add sufficient salt (Note 4), of either the anhydrous (Na_2SO_4) or the crystalline ($Na_2SO_4 \cdot 10H_2O$) form,[5] to ensure not only saturation but also the presence of excess crystals when the solution is ready for use in the tests. Thoroughly stir the mixture during the addition of the salt and stir the solution at frequent intervals until used. To reduce evaporation and prevent contamination, keep the solution covered at all times when access is not needed. Allow the solution to cool to 70 ± 2 F (21 ± 1 C). Again stir, and allow the solution to remain at the designated temperature for at least 48 h before use. Prior to each use, break up the salt cake, if any, in the container, stir the solution thoroughly, and determine the specific gravity of the solution. When used, the solution shall have a specific gravity not less than 1.151 nor more than 1.174. Discard a discolored solution, or filter it and check for specific gravity.

NOTE 4—For the solution, 215 g of anhydrous salt or 700 g of the decahydrate per liter of water are sufficient for saturation at 71.6 F (22 C). However, since these salts are not completely stable and since it is desirable that an excess of crystals be present, the use of not less than 350 g of the anhydrous salt or 750 g of the decahydrate salt per liter of water is recommended.

4.1.2 *Magnesium Sulfate Solution*—Prepare a saturated solution of magnesium sulfate by dissolving a USP or equal grade of the salt in water at a temperature of 77 to 86 F (25 to 30 C). Add sufficient salt (Note 5), of either the anhydrous ($MgSO_4$) or the crystalline ($MgSO_4 \cdot 7H_2O$) (Epsom salt) form, to ensure saturation and the presence of excess crystals when the solution is ready for use in the tests. Thoroughly stir the mixture during the addition of the salt and stir the solution at frequent intervals until used. To reduce evaporation and prevent contamination, keep the solution covered at all times when access is not needed. Allow the solution to cool to 70 ± 2 F (21 ± 1 C). Again stir, and allow the solution to remain at the designated temperature for at least 48 h before use. Prior to each use, break up the salt cake, if any, in the container, stir the solu-

[5] Experience with the test method indicates that a grade of sodium sulfate designated by the trade as dried powder, which may be considered as approximately anhydrous, is the most practical for use. That grade is more economically available than the anhydrous form. The decahydrate sodium sulfate presents difficulties in compounding the required solution on account of its cooling effect on the solution.

tion thoroughly, and determine the specific gravity of the solution. When used, the solution shall have a specific gravity not less than 1.295 nor more than 1.308. Discard a discolored solution, or filter it and check for specific gravity.

NOTE 5—For the solution, 350 g of anhydrous salt or 1230 g of the heptahydrate per litre of water are sufficient for saturation at 73.4 F (23 C). However, since these salts are not completely stable, with the hydrous salt being the more stable of the two, and since it is desirable that an excess of crystals be present, it is recommended that the heptahydrate salt be used and in an amount of not less than 1400 g/litre of water.

5. Samples

5.1 *Fine Aggregate*—Fine aggregate for the test shall be passed through a ³/₈-in. (9.5-mm) sieve. The sample shall be of such size that it will yield not less than 100 g of each of the following sizes, which shall be available in amounts of 5 percent or more, expressed in terms of the following sieves:

Passing Sieve	Retained on Sieve
No. 30 (600-μm)	No. 50 (300-μm)
No. 16 (1.18-mm)	No. 30 (600-μm)
No. 8 (2.36-mm)	No. 16 (1.18-mm)
No. 4 (4.75-mm)	No. 8 (2.36-mm)
⅜ in. (9.5-mm)	No. 4 (4.75-mm)

5.2 *Coarse Aggregate*—Coarse aggregate for the test shall consist of material from which the sizes finer than the No. 4 sieve have been removed. The sample shall be of such a size that it will yield the following amounts of the indicated sizes that are available in amounts of 5 percent or more:

Size (Square-Opening Sieves)	Weight, g
⅜ in. (9.5 mm) to No. 4 (4.75 mm)	300 ± 5
¾ (19.0 mm) to ⅜ in.	1000 ± 10
Consisting of:	
½ (12.5 mm) to ⅜-in. material	330 ± 5
¾ to ½-in. material	670 ± 10
1½ (37.5 mm) to ¾ in.	1500 ± 50
Consisting of:	
1 (25.0 mm) to ¾-in. material	500 ± 30
1½ to 1-in. material	1000 ± 50
2½ (63 mm) to 1½ in.	5000 ± 300
Consisting of:	
2 (50 mm) to 1½-in. material	2000 ± 200
2½ to 2-in. material	3000 ± 300
Larger sizes by 1-in. spread in sieve size, each fraction	7000 ± 1000

5.3 When an aggregate to be tested contains appreciable amounts of both fine and coarse material, having a grading with more than 10 weight percent coarser than the ⅜-in. (9.5-mm) sieve and, also, more than 10 weight cent finer than the No. 4 (4.75-mm) si test separate samples of the minus No. 4 f tion and the plus No. 4 fraction in accordа with the procedures for fine aggregate coarse aggregate, respectively. Report the sults separately for the fine aggregate frac and the coarse aggregate fraction, giving percentages of the coarse and fine size f tions in the initial grading.

6. Preparation of Test Sample

6.1 *Fine Aggregate*—Thoroughly wash sample of fine aggregate on a No. 50 (300 sieve, dry to constant weight at 230 ± ' (110 ± 5 C), and separate into the diffe sizes by sieving, as follows: Make a ro separation of the graded sample by me of a nest of the standard sieves specifiec 5.1. From the fractions obtained in this m ner, select samples of sufficient size to y 100 g after sieving to refusal. (In gene a 110-g sample will be sufficient.) Do use fine aggregate sticking in the meshes the sieves in preparing the samples. We samples consisting of 100 ± 0.1 g out of e of the separated fractions after final siev and place in separate containers for the t

6.2 *Coarse Aggregate*—Thoroughly w and dry the sample of coarse aggregate constant weight at 230 ± 9 F (110 ± 5 and separate it into the different sizes sh in 5.2 by sieving to refusal. Weigh out qua ties of the different sizes within the tolera of 5.2 and, where the test portion consist two sizes, combine them to the design total weight. Record the weights of the samples and their fractional components the case of sizes larger than ¾ in., re the number of particles in the test sam

7. Procedure

7.1 *Storage of Samples in Solution*—merse the samples in the prepared solı of sodium sulfate or magnesium sulfate not less than 16 h nor more than 18 such a manner that the solution covers to a depth of at least ½ in. (Note 6). C the containers to reduce evaporation prevent the accidental addition of extra substances. Maintain the samples imm of the solution at a temperature of 70 ± 2 F (21 ± 1 C) for the immersion period.

NOTE 6—Suitably weighted wire grids placed over the sample in the containers will permit this coverage to be achieved with very lightweight aggregates.

7.2 *Drying Samples After Immersion*—After the immersion period, remove the aggregate sample from the solution, permit it to drain for 15 ± 5 min, and place in the drying oven. The temperature of the oven shall have been brought previously to 230 ± 9 F (110 ± 5 C). Dry the samples at the specified temperature until constant weight has been achieved. Establish the time required to attain constant weight as follows: with the oven containing the maximum sample load expected, check the weight losses of test samples by removing and weighing them, without cooling, at intervals of 2 to 4 h; make enough checks to establish required drying time for the least favorable oven location (see 3.5) and sample condition (Note 7). Constant weight will be considered to have been achieved when weight loss is less than 0.1 percent of sample weight in 4 h of drying. After constant weight has been achieved, allow the samples to cool to room temperature, when they shall again be immersed in the prepared solution as described in 7.1.

NOTE 7—Drying time required to reach constant weight may vary considerably for several reasons. Efficiency of drying will be reduced as cycles accumulate because of salt adhering to particles and, in some cases, because of increase in surface area due to breakdown. The different size fractions of aggregate will have differing drying rates. The smaller sizes will tend to dry more slowly because of their larger surface area and restricted interparticle voids, but this tendency may be altered by the effects of container size and shape.

7.3 *Number of Cycles*—Repeat the process of alternate immersion and drying until the required number of cycles is obtained.

8. Quantitative Examination

8.1 Make the quantitative examination as follows:

8.1.1 After the completion of the final cycle and after the sample has cooled, wash the sample free from the sodium sulfate or magnesium sulfate as determined by the reaction of the wash water with barium chloride ($BaCl_2$). Wash by circulating water at 110 ± 10 F (43 ± 6 C) through the samples in their containers. This may be done by placing them in a tank into which the hot water can be introduced near the bottom and allowed to overflow. In the washing operation, the samples shall not be subjected to impact or abrasion that may tend to break up particles.

8.1.2 After the sodium sulfate or magnesium sulfate has been removed, dry each fraction of the sample to constant weight at 230 ± 9 F (110 ± 5 C). Sieve the fine aggregate over the same sieve on which it was retained before the test, and sieve the coarse aggregate over the sieve shown below for the appropriate size of particle. For fine aggregate, the method and duration of sieving shall be the same as were used in preparing the test samples. For coarse aggregate, sieving shall be by hand, with agitation sufficient only to assure that all undersize material passes the designated sieve. No extra manipulation shall be employed to break up particles or cause them to pass the sieves. Weigh the material retained on each sieve and record each amount. The difference between each of these amounts and the initial weight of the fraction of the sample tested is the loss in the test and is to be expressed as a percentage of the initial weight for use in Table 1.

Size of Aggregate	Sieve Used to Determine Loss
2½ (63 mm) to 1½ in. (37.5 mm)	1¼ in. (31.5 mm)
1½ to ¾ in. (19.0 mm)	⅝ in. (16.0 mm)
¾ to ⅜ in. (9.5 mm)	5/16 in. (8.0 mm)
⅜ in. to No. 4 (4.75 mm)	No. 5 (4.0 mm)

9. Qualitative Examination

9.1 Make a qualitative examination of test samples coarser than ¾ in. (19.0 mm) as follows (Note 8);

9.1.1 Separate the particles of each test sample into groups according to the action produced by the test (Note 8).

9.1.2 Record the number of particles showing each type of distress.

NOTE 8—Many types of action may be expected. In general, they may be classified as disintegration, splitting, crumbling, cracking, flaking, etc. While only particles larger than $^{3}/_{4}$ in. in size are required to be examined qualitatively, it is recommended that examination of the smaller sizes be made in order to determine whether there is any evidence of excessive splitting.

10. Report

10.1 The report shall include the following data (Note 9):

10.1.1 Weight of each fraction of each sample before test.

10.1.2 Material from each fraction of the sample finer than the sieve designated in 8.1.2 for sieving after test, expressed as a percentage of the original weight of the fraction.

10.1.3 Weighted average calculated from the percentage of loss for each fraction, based on the grading of the sample as received for examination or, preferably, on the average grading of the material from that portion of the supply of which the sample is representative except that:

10.1.3.1 For fine aggregates (with less than 10 percent coarser than the $^{3}/_{8}$-in. (9.5-mm) sieve), assume sizes finer than the No. 50 (300-μm) sieve to have 0% loss and sizes coarser than the $^{3}/_{8}$-in. (9.5-mm) sieve to have the same loss as the next smaller size for which test data are available.

10.1.3.2 For coarse aggregate (with less than 10 percent finer than the No. 4 (4.75-mm) sieve), assume sizes finer than the No. 4 (4.75-mm) sieve to have the same loss as the next larger size for which test data are available.

10.1.3.3 For an aggregate containing appreciable amounts of both fine and coarse material tested as two separate samples as required in 5.3, compute the weighted average losses separately for the minus No. 4 and plus No. 4 fractions based on recomputed gradings considering the fine fraction as 100 percent and the coarse fraction as 100 percent. Report the results separately giving the percentage of the minus No. 4 and plus No. 4 material in the initial grading.

10.1.3.4 For the purpose of calculating the weighted average, consider any sizes in 5.1 or 5.2 that contain less than 5 percent of the sample to have the same loss as the average of the next smaller and the next larger size, or if one of these sizes is absent, to have the same loss as the next larger or next smaller size, whichever is present.

10.1.4 In the case of particles coarser than $^{3}/_{4}$ in. (19.0 mm) before test: (*1*) The number of particles in each fraction before test, and (*2*) the number of particles affected, classified as to number disintegrating, splitting, crumbling, cracking, flaking, etc., as shown in Table 2.

10.1.5 Kind of solution (sodium or magnesium sulfate) and whether the solution was freshly prepared or previously used.

NOTE 9—Table 1, shown with test values inserted for purpose of illustration, is a suggested form for recording test data. The test values shown might be appropriate for either salt, depending on the quality of the aggregate.

11. Precision

11.1 For coarse aggregate with weighted average sulfate soundness losses in the range of 6 to 16 percent for sodium and 9 to 20 percent for magnesium, the precision indexes are as follows:

	Coefficient of Variation (1S%), Percent[a]	Difference Between Two Tests (D2S%), Percent of Average[a]
Multilaboratory:		
Sodium sulfate	41	116
Magnesium sulfate	25	71
Single-Operator:		
Sodium sulfate	24	68
Magnesium sulfate	11	31

[a] These numbers represent, respectively, the (1S%) and (D2S%) limits as described in Recommended Pract C 670.

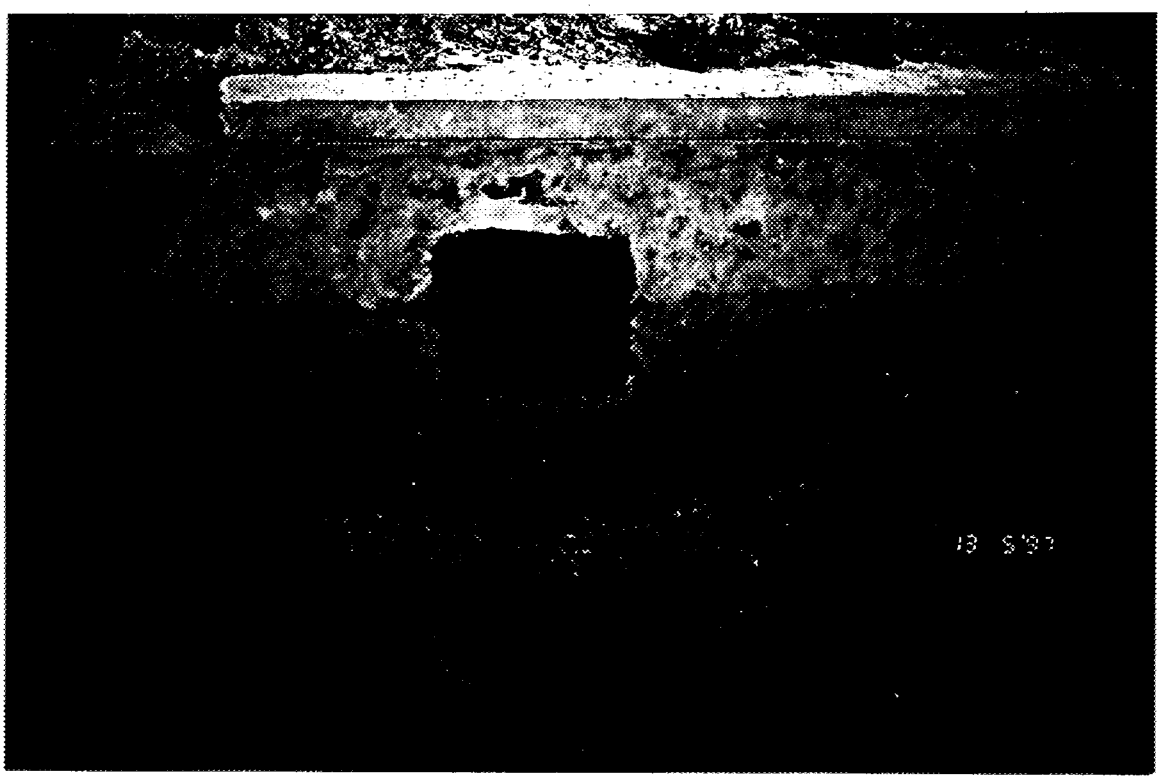
Appendix C
Petrographic Examination of Aggregate

HALCROW

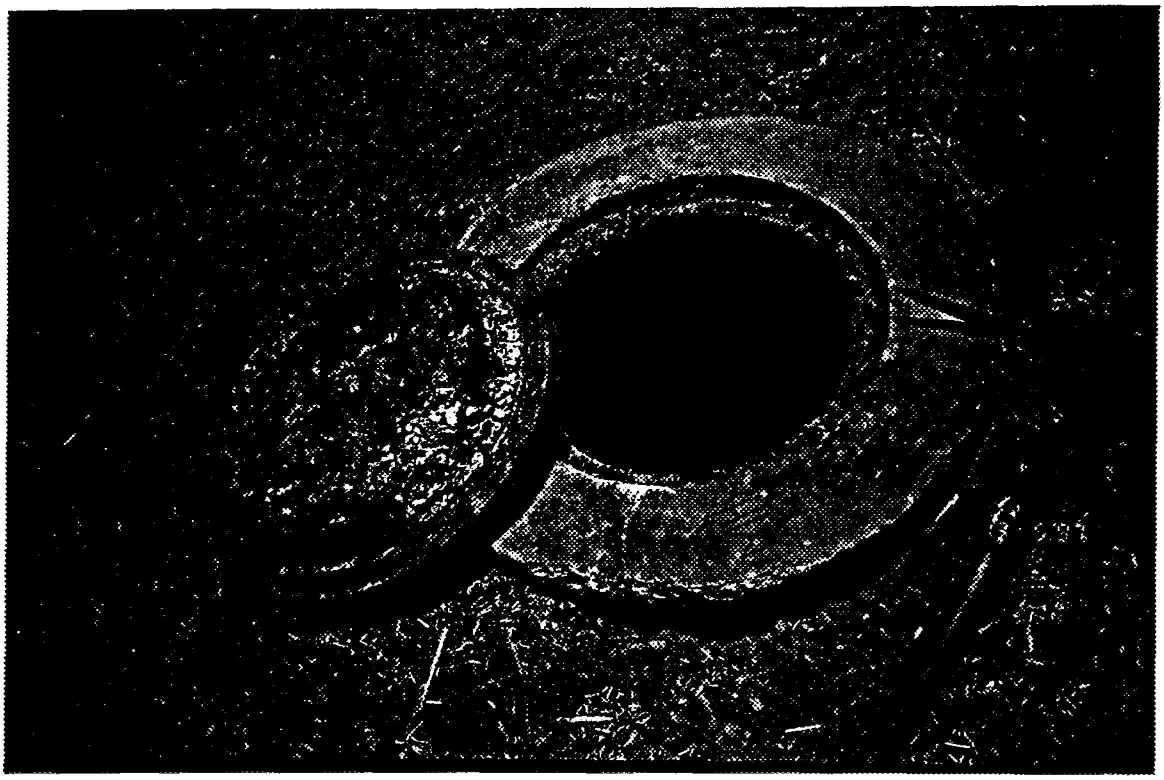
Photograph 1 Final Discharge to the Pandoki Drain

Photograph 2 (Looking Downstream) Box Structure Three at Second Crossing of Rohi Nallah, Showing Box Structure Four in the Background

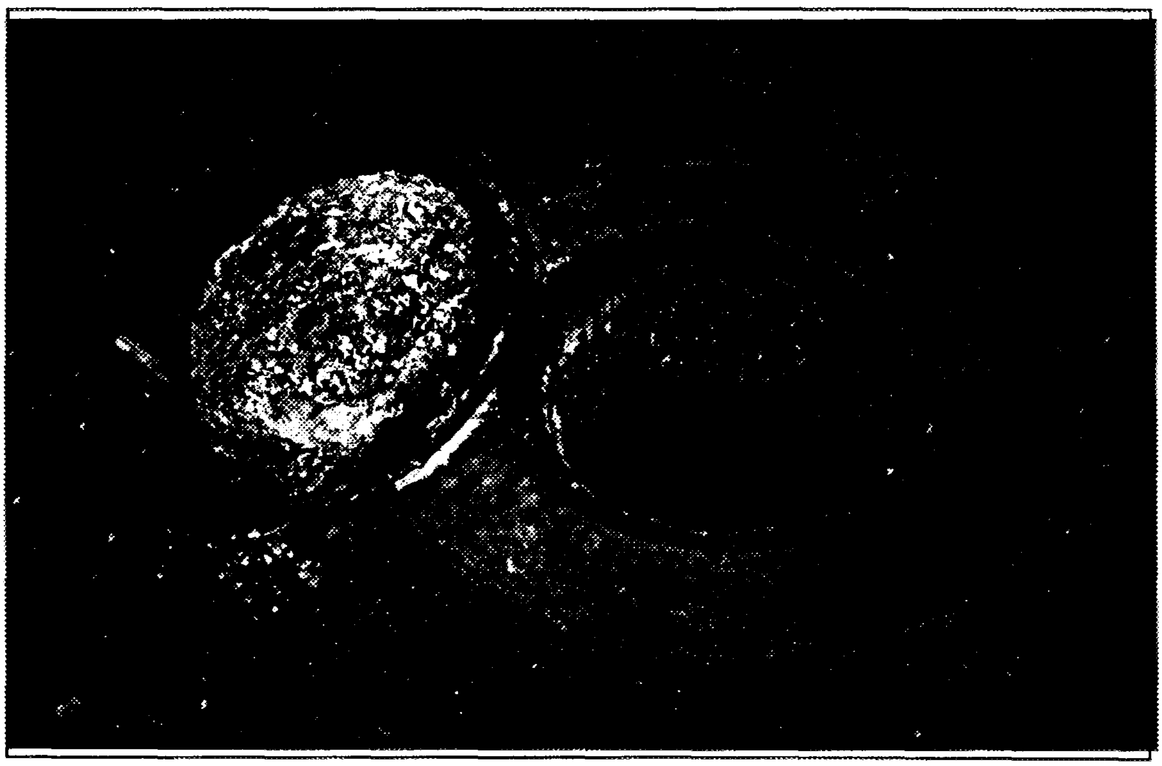
Photograph 3 Concrete Sampling with Drill Press Mounted Core Cutting Machine



Photograph 4 Repaired Surface of Open-channel Wall

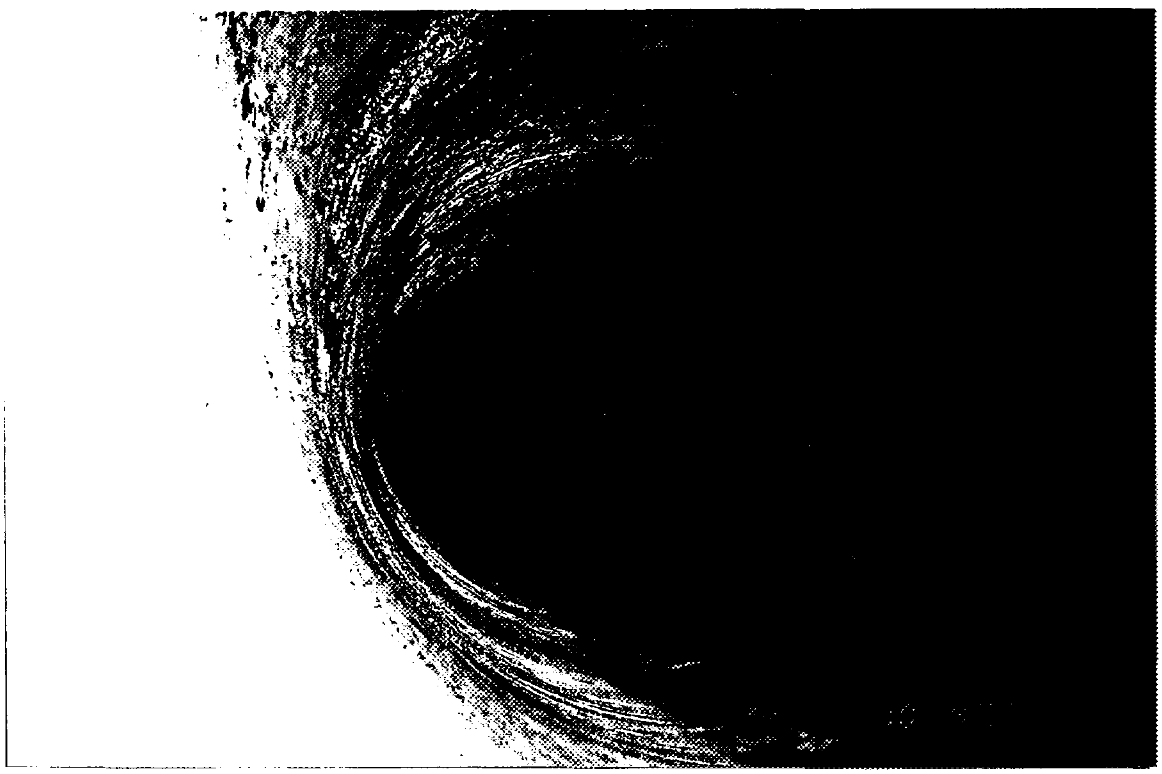


Photograph 5 Honeycombing of Concrete in Manhole Cover



Photograph 6 Acid Attack on a Manhole Cover

Photograph 7 A Concrete Pole Within the Constructed Open-channel



Photograph 8 Salt Build-up on the Crown of Concrete Pipe

Appendix A
Three Edge Bearing Test Results

HALCROW

بسم اللہ الرحمن الرحیم

C.T.L. 3.

3-Edge
54"

?graphic Address: 'LABTEST' LAHORE
Telephone No. { 852664 / 850376

GOVERNMENT OF PAKISTAN

CENTRAL TESTING LABORATORIES

FEROZEPUR ROAD
LAHORE-16

Your Ref. No. KTFCP/EE/11-33 — Our Ref. No CTL/4(288)/96-97(1707)

dated :- 12-06-1996. — dated :- 04-07-1996.

(Samples received on 04-07-1996).

TEST REPORT

Sample received from / Report issued to: Executive Engineer, Kasur Tannery Pollution Control Project, Tehsil Road, KASUR.

No. of samples: Two (2).

Specification against which tested: As per test request.

Subject:- Testing of samples stated to be R.C.C. Pipes of 54" stated dia. (Kasur Tanneries Pollution Control Project).

The samples as received have been tested with the following test results:-

S.No.	Labs.Registration Nos. & Identification Marks.	Effective Length. (Feet).	Load at the appearance of 0.01" Thickness Crack (Tons).	Ultimate Crushing Load (Three age bearing test) (Tons).
1.	C/60 (G-225, 25-3-96).	7.25	17.56	28.10
2.	C/61 (G-305, 7-4-96).	7.25	16.06	28.30

Remarks:-1). The above test results pertain to the samples supplied to these Labs.

2). In case of overtyping, erasing or doubtful results, the matter shall be referred to the Dy. Director Incharge immediately for verification.

According to ASTM C-76 Class II Wall B
The Three Edge bearing Test carried over
for 54" i/d RCC Pipe pertaining to work
of ... ... is quite safe
against required minimum load as

$\frac{1000 \times 7.25 \times 4.5}{2240} = 14.56$ Tons for hair crack ...

SARWAR

DEPUTY DIRECTOR INCHARGE
CENTRAL TESTING LABORATORIES
(56787)

بسم اللہ الرحمن الرحیم

C.T.L. 3.

Telegraphic Address ; 'LABTEST' LAHORE

Telephone No. { 852664 850375

GOVERNMENT OF PAKISTAN

CENTRAL TESTING LABORATORIES

FEROZEPUR ROAD
LAHORE-16

Your Ref. No.:-KTPCP/EE/11-35.

dated :-18-6-1996.
(Samples received on 11-7-1996).

Our Ref. No.:-CTL/4(288)/96-97

dated :-14-7-1996. (1766

TEST REPORT

Sample received from / Report issued to: The Executive Engineer, Kasur Tanneries Pollution Control Project, Tehsil Road, KASUR.

No. of samples Two(2).

Specification against which tested As per test request.

SUBJECT:- Testing of samples stated tobe "R.C.C. Pipes of 54" Stated [
(Construction of Kasur Tanneries Pollution Control Project).

The above samples were tested with the following test results:-

S.Nos.	Labs.Registration No.& Identification Mark.	Effective Length. (Feet).	Load at the appearance of 0.01" Thick Crack. (Tons).	Ultimate Crus[Load.(Three e[bearing Test. (Tons).
1.	C/120 (378).	7.58	16.057	24.58
2.	C/121 (398).	7.58	16.460	25.49

Remarks:- 1). The above samples were tested in the presence of part[
representative Mr.Abdul Sattar Lillah, Exective Engine[
KTWMA, Kasur.

2). In case of overtyping, erasing or doubtful results the matter shall be referred to the Dy.Director Incharge immediately for verification.

بسم اللہ الرحمن الرحیم

Tele... Address: LABTEST' LAHORE
Telephone No. 852664 / 850375

GOVERNMENT OF PAKISTAN
CENTRAL TESTING LABORATORIES
FEROZEPUR ROAD
LAHORE-16

Your Ref. No. KTPCP/EE/11-34 | Our Ref. No. CTL/4(288)/96-97

dated :- 18-06-1996. | dated :- 11-08-1996. (2043)

(Samples received on 07-08-1996).

TEST REPORT

Sample received from / Report issued to: Executive Engineer, KTWMA, Tehsil Road, KASUR.

No. of samples: Two (2).

Specification against which tested: As per test request.

Subject:- Testing of samples stated to be "R.C.C. Pipes of 54" stated dia". (Kasur Tanneries Pollution Control Project). (By: M/S. Akhtar Hussain, Gujranwala).

The above samples were tested with the following test results:-

S.No.	Labs. Registration Nos. & Identification Marks.	Effective Length. (Feet).	Load at the Appearance of 0.01" crack. (Tons).	Three Edge Bearing Test. (Ultimate Crushing Load). (Tons).
1.	C/371 (738).	7.25	20.57	25.79
2.	C/372 (620).	7.25	19.57	26.39

Remarks:- 1). The above samples were tested in the presence of party representative Mr. Saifullah, S.D.O-II, KTPCP, Kasur.

2). The above test results pertain to the samples supplied to these Labs.

3). In case of overtyping, erasing or doubtful results, the matter shall be referred to the Dy. Director Incharge immediately for verification.

DEPUTY DIRECTOR INCHARGE
CENTRAL TESTING LABORATORIES
LAHORE

SARWAR/

(37034).

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M/s Chaudhry ... C.T.L. 3
Part IV: Group IV

Telegraphic Address : "LABTEST" LAHORE
Telephone No. 852664, 850375

GOVERNMENT OF PAKISTAN

CENTRAL TESTING LABORATORIES

FEROZEPUR ROAD
LAHORE-16

Your Ref. No. KTPCP/EE/11-42 — Our Ref. No. CTL/4(288)/96-97
dated :- 25-06-1996. — dated :- 09-09-1996. (2294)
(Samples received on 08-09-1996).

TEST REPORT

Sample received from / Report issued to: Executive Engineer, KTWMA, Tehsil Road, KASUR.

No. of sample: Two (2).

Specification against which tested: As per test request.

Subject:- Testing of samples stated to be "R.C.C. Pipes of 54" Stated Dia". (Kasur Tanneries Pollution Control Project.)

The above samples were tested with the following test results:-

S.No.	Labs.Registration Nos. & Identification Marks.	Effective Length. (Feet).	Load at the Appearance of 0.01" Crack (Tons)	Three Edge Bearing Tes (Ultimate Crushing Lo (Tons).
1.	C/637 (P-117 dated 24-07-1996).	7.666	20.2	26.5
2.	C/638 (P-116 dt.23-7-96).	7.666	21.6	27.1

Remarks:- 1). The above samples were tested in the presence of party representative Mr. Abdul Sattar Lillah, XEN.

2). The above test results pertain to the samples supplied t these Labs.

3). In case of overtyping, erasing or doubtful results, the matter shall be referred to the Dy. Director Incharge immediately for verification.

Appendix E
Cube Compressive Strength as a Function of the Rebound Number

HALCROW

Cube Compressive Strength as a Function of the Rebound Number R

R	14–56 Days						7 Days					
	W_m			W_{min}			W_m			W_{min}		
	kp/cm^2	N/mm^2	psi	kp/cm^2	N/mm^2	psi	kp/cm^2	N/mm^2	psi	kp/cm^2	N/mm^2	psi
20	101	9.9	1440	54	5.3	770	121	11.9	1720	74	7.3	1050
21	113	11.1	1610	64	6.3	910	132	12.9	1880	83	8.1	1180
22	126	12.4	1790	75	7.4	1070	145	14.2	2060	94	9.2	1340
23	139	13.6	1980	86	8.4	1220	157	15.4	2230	104	10.2	1480
24	152	14.9	2160	98	9.6	1390	169	16.6	2400	115	11.3	1640
25	166	16.3	2360	110	10.8	1560	183	18.0	2600	127	12.5	1810
26	180	17.7	2560	122	12.0	1740	196	19.2	2790	138	13.5	1960
27	195	19.1	2770	135	13.2	1920	210	20.6	2990	150	14.7	2130
28	210	20.6	2990	149	14.6	2120	225	22.1	3200	164	16.1	2330
29	225	22.1	3200	163	16.0	2320	239	23.4	3400	177	17.4	2520
30	241	23.6	3430	178	17.5	2530	254	24.9	3610	191	18.7	2720
31	257	25.2	3660	193	18.9	2750	269	26.4	3830	205	20.1	2920
32	274	26.9	3900	209	20.5	2970	285	28.0	4050	220	21.6	3130
33	291	28.5	4140	225	22.1	3200	300	29.4	4270	234	23.0	3330
34	307	30.1	4370	240	23.5	3410	315	30.9	4480	248	24.3	3530
35	324	31.8	4610	256	25.1	3640	331	32.5	4710	263	25.8	3740
36	342	33.5	4860	273	26.8	3880	348	34.1	4950	279	27.4	3970
37	360	35.3	5120	290	28.4	4120	365	35.8	5190	295	28.9	4200
38	377	37.0	5360	307	30.1	4370	381	37.4	5420	311	30.5	4420
39	395	38.7	5620	324	31.8	4610	398	39.0	5660	327	32.1	4650
40	413	40.5	5870	341	33.4	4850	416	40.8	5920	344	33.7	4890
41	432	42.4	6150	359	35.2	5110	434	42.6	6170	361	35.4	5130
42	450	44.1	6400	377	37.0	5360	451	44.2	6410	378	37.1	5380
43	469	46.0	6670	395	38.7	5620	470	46.1	6690	396	38.8	5630
44	488	47.9	6940	414	40.6	5890	488	47.9	6940	414	40.6	5890
45	507	49.7	7210	432	42.4	6140	507	49.7	7210	432	42.4	6140
46	526	51.6	7480	451	44.2	6410	526	51.6	7480	451	44.2	6410
47	546	53.5	7770	470	46.1	6690	546	53.5	7770	470	46.1	6690
48	565	55.4	8040	489	48.0	6960	565	55.4	8040	489	48.0	6960
49	584	57.3	8310	508	49.8	7230	584	57.3	8310	508	49.8	7230
50	604	59.2	8590	527	51.7	7500	604	59.2	8590	527	51.7	7500
51	623	61.1	8860	546	53.5	7770	623	61.1	8860	546	53.5	7770
52	643	63.1	9150	565	55.4	8040	643	63.1	9150	565	55.4	8040
53	663	65.0	9430	584	57.3	8310	663	65.0	9430	584	57.3	8310
54	683	67.0	9710	603	59.1	8580	683	67.0	9710	603	59.1	8580
55	703	68.9	10000	622	61.0	8850	703	68.9	10000	622	61.0	8850