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REHABILITATION OF BARRAGES AND HEADWORKS FOR PUNJAB-PAKISTAN

VOLUME 4 JINNAH BARRAGE

HARZA ENGINEERING COMPANY
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FOR
REHABILITATION
OF
BARRAGES AND HEADWORKS
FOR
PUNJAB, PAKISTAN.

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ABBREVIATIONS USED IN THIS REPORT

S.E:	SUPERINTENDING ENGINEER
XEN:	EXECUTIVE ENGINEER
SDO:	SUB-DIVISIONAL OFFICER
PID:	PROVINCIAL IRRIGATION DEPARTMENT
NESPAK:	NATIONAL ENGINEERING SERVICE PAKISTAN
MIW:	MOGHALPURA IRRIGATION WORKSHOP
BIW:	BHALWAL IRRIGATION WORKSHOP
USAID:	UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT
AID:	AGENCY FOR INTERNATIONAL DEVELOPMENT
PIO/C:	PROJECT IMPLEMENTATION ORDER, COMMODITIES
PIL:	PROJECT IMPLEMENTATION LETTER
ISM-II:	IRRIGATION SYSTEM MANAGEMENT-II
O&M:	OPERATION AND MAINTENANCE

EXECUTIVE SUMMARY

The Indus basin irrigation system in Pakistan is the largest contagious irrigation system in the world. There are about 40,000 miles of canals and 250,000 miles of public watercourses. Since independence in 1947, Pakistan's strategy for utilizing and maintaining this vast system has been in three areas (1) conservation of water and modernizing the conveyance system (2) reclamation and control of salinity and waterlogging; and (3) improvement in delivery of water to the users. O&M has been neglected and this has contributed to the deterioration of the entire system. This was brought to the attention of all concerned when a gate on the Sukkar barrage failed in 1982.

As a result of this failure and the ensuing investigation, other barrages of the system were inspected by several different groups. These inspections revealed the extensively deteriorated condition of the gates and gearing of most of the barrages and headworks. This has happened over an extended period of time and most of these structures are in need of immediate repair or overhauling to safeguard the system.

It was not until the Harza gate specialist came to Pakistan in January 1990 that the extent of the wear and the difficulty of performing these repairs was realized. The most difficult parts to repair would be the roller tracks; these tracks are an integral part of the cast iron gate groove which is a permanent part of the concrete and masonry pier. It would be impossible to replace them without destroying the entire barrage. After an inspection of Taunsa and Jinnah barrage by the PID and Harza Engineers, it was decided to preliminarily concentrate the efforts for barrage gate repair, as proposed in ISM-II Project workplan, at Jinnah Barrage.

The Jinnah barrage was constructed from 1939 to 1943 and functioned as intended until about 1980. It was at this time that the gate operational problems started. This problem persisted with all 57 of the gates until the closure of 1990-91 when 32 gate roller paths (tracks) for 16 gates were machined and replaced utilizing the new procedure developed by the PID. However, in 1982 an attempt was made to repair the roller paths of the gates by welding a mild steel plate to the cast iron groove. This plate was in the form of a wedge, thick at the bottom and thin at the top. This repair did not prove to be effective as the plates either broke off, became deformed and jammed the roller trains or made the operation of the gates very difficult or impossible.

Several recommendations for repair or modification were made by various individuals and inspection teams. However, the report of Mr. C.K. Sehgal of Harza made several specific proposals for these repairs, and how these proposals could be implemented. The gate roller tracks were identified as the point where most of the wear had taken place, this was the major reason for the gates sticking and being difficult to operate. Of the various methods of repair advanced in Sehgal's report, the use of "a purpose made machine to grind away the worn portion of the gate roller track so a

replacement plate could be installed", was the technique that was selected. However, after much discussion, the idea of grinding the cast iron was discarded: one of the machinist at M.I.W suggested milling or cutting the groove with a "purpose made machine".

The Executive Engineer (XEN) of M.I.W then proceeded to implement this idea, with the advise and counsel of his staff and the Harza engineers. The first machine was built at Moghalpura Irrigation Workshop in May and June of 1990. It was tested, modifications were made and a final design was agreed upon after a second machine was constructed and tested and found to perform in a manner that was deemed satisfactory.

In August of 1990 Mr. C.K. Sehgal was brought to Lahore for a second consultation. Mr. Sehgal reviewed the plan that had been developed to carry out the gate repairs, evaluated proposed material to be utilized in the repairs and made recommendations concerning the materials and their specifications. Mr. Sehgal also observed the portable milling machine being operated in the,"mock-up", groove at Moghalpura Irrigation Workshop and was impressed with the excellent machined surface it provided for installation of the replacement track plate. Mr. Sehgal made several recommendations that were incorporated in the workplan for the proposed work at Jinnah barrage and for the use of the machine to mill off the worn portion of the gate tracks.

The original plan for the 1990-91 closure period was to construct 20 milling machines, 10 right and 10 left hand, to do the resurfacing of 64 roller paths of 32 gate bays; replace the roller paths with the new cast iron plates, reassemble the remaining parts of the gate system and check to see that the gates operate properly.

Mr. Jaseem Khalid Jaffri, a metallurgist, was retained by Harza to provide the technical expertise that would be needed to make certain that the replacement plates to be manufactured, from "Pearlitic Ductile Cast Iron", at a commercial foundry, were produced according to the specifications previously agreed upon. Rastgar foundry in Islamabad was selected for the production of the plates by the PID, under the guidance of Mr. Jaffri. The plates were manufactured in Islamabad, then delivered to the Moghalpura workshop, where the final machining and drilling of holes for the attachment screws was completed prior to delivery to the barrage.

The work of constructing the coffer dam was done by contractors supervised by the barrage division. The mechanical work of removing the roller trains and guards, machining the groove, installation of the new roller track plates and replacement of roller trains and guards was done by the staff of M.I.W. A work force of approximately 150 workshop technicians with different skills performed the tasks that were necessary to complete the work. There were nine M.I.W supervisory staff four Harza engineers and the S.E. Mechanical involved in overseeing the activities of the entire mechanical force. The work had to be completed during the limited closure period which was from Jan. 13 to Feb. 2 1991.

The work started slowly as this was the first time that these procedures had been tried under actual field conditions. To begin with it took seven days to complete one gate bay; however, this time was reduced to 5 days as experience was gained. In addition to the roller tracks the roller trains and rocker assemblies plus the roller guards had to be inspected to determine if replacement or repair was needed. Repairs were made as long as replacement parts were available; however, some of the roller trains that were damaged had to be reused.

The original work plan had to be modified as the work progressed because of unforeseen problems that were encountered. It was found that the tools available would not drill into the masonry of the pier, this prevented the use of rawl plugs to secure the milling machine. A second obstacle which presented itself was the length of the replacement plate, these were cast 10 feet long; however, the worn area of the gate track varied from 11 to 14 feet. The replacement plates had to be cut and spliced to cover the area of wear. All of these difficulties took time to solve, this delayed the work and resulted in only half of the planned 64 gate tracks being machined and replaced.

An assessment of additional needed repairs for the structure was made while the repair work was being carried out. Follow-up on what was found is in progress but to date no remedial action has been taken.

Observations and suggestions have been included as a part of the report and would contribute to improving working conditions and procedures if they are noted and incorporated in future work plans.

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HARZA ENGINEERING COMPANY, ISM-II PROJECT, M.I.W, LAHORE.

REHABILITATION OF BARRAGES AND HEAD WORKS FOR PAKISTAN

BACKGROUND

The Indus Basin irrigation system in Pakistan is the largest contiguous irrigation system in the world. Flowing from the Indus River and six tributaries, this system has three major storage reservoirs, 19 barrages, and 43 canal commands and serves a total cultivable area of 34 million acres. Canals fed by the Indus and its tributaries total about 40,000 miles, in turn, feeding an additional 250,000 miles of public watercourses. In addition to its size, the Indus Basin area is characterized by low channel gradients, high sediment loads and complex groundwater conditions. Irrigation water in the Punjab and the Sindh is drawn almost entirely from the Indus Basin surface and ground waters. However, in Baluchistan and the Northwest Frontier Provinces small irrigation systems lying outside the Indus Basin are common.

Since its independence, Pakistan's strategy for the Indus Basin has focused on three areas: (1) conservation of water and redesign of the conveyance system to effectively use water available under the Indus Basin Treaty; (2) reclamation and control of salinity and waterlogging; and (3) improvement in the delivery of water to farmers fields. The concentration of effort in these areas contributed to the neglect of essential operation and maintenance (O&M) activities. This was particularly unfortunate because with the completion of the link canals the total supply of water in the system increased and hence the need for timely maintenance.

As a result, water distribution became increasingly unreliable, and inequities in distribution between head-enders and tail-enders grew more pronounced. Additionally, over-toppings and breaches of canals caused damage to crops and households while inadequate or poorly functioning drains failed to remove seasonal water surpluses or raised groundwater tables. Another element of the system which has suffered greatly from this lack of maintenance has been the gates and gearing of the barrages and headworks. Many of these gates have developed alarming major operational defects due to deterioration over a passage of time and are in immediate need of major repair in order to properly regulate and safeguard the system.

INTRODUCTION:

The need to carry out gate repairs was recognized early in the Irrigation System Management II (ISM II) Project. Two reports were prepared in 1988 and submitted to the PID. The first was written and submitted by Sir. M. MacDonald and Partners Limited of Cambridge, England in January 1988; the second was developed and submitted by two teams of PID engineers of the Mechanical Circle, Lahore in April 1988. The report by M. MacDonald covered only Jinnah barrage. The second report refers to the 13 barrages of Punjab. Both reports recognize a need for remedial action and makes suggestions as to the methods to be used for making the needed repairs. However, the degree of wear that had occurred on the gate tracks and the difficulty of preforming those repairs was not realized until the Harza Engineering Gate Specialist came to Pakistan in January 1990 at the request of the Punjab government to review and inspect the gates, determine their current condition and advise remedial measures. An inspection was carried out on five selected Barrages in the Punjab Province. A report was prepared giving a detailed explanation of the condition of the gates and recommendations for action.

The following is a quote from the Executive Summary of that report: "Nearly all of the gates are in poor condition and need immediate attention.

The report categorizes the condition as Tolerable and Serious. The difference between Tolerable and Serious categories is minimal; this distinction is made to help establish priorities for rehabilitation.

From a safety viewpoint, of great concern is the corrosion of the gate structural members and the condition of the wire ropes. Their replacement should receive the highest priority. Also to keep the gates in operation, the worn tracks and the rollers need to be repaired urgently to prevent jamming of the gates".

The following is an excerpt from the report that discusses the gate track condition and the recommendations for repair.

"Roller tracks at each of the barrages were found to be substantially worn near the bottom where the hydrostatic load is maximum. The height of the wear equals the travel height of the rollers which is equal to half the gate travel (the gates are stony type with rollers not attached to the gates, but simply placed between the gates and the tracks). Some tracks were worn more than others. The following are some of the reasons:

1. Difference in hydrostatic load
2. Age of the barrage
3. Frequency of use
4. Difference in materials of the tracks and the rollers at different barrages.

The difference in materials appears to be the most important factor. Although cast iron has been used for the tracks at all barrages, the installation (and presumably the fabrication) of the gates at each barrages took place at a different time and at least three different firms (one from Amritsar, India, Brown and Root from the USA located at Bhalwal, Pakistan constructed Taunsa barrage and one from Scotland) participated in the fabrication. Presumably the quality of cast iron in each case was different. The difference in the materials for the rollers (cast iron at Islam, hardened stainless steel at Taunsa, mild steel at Panjnad and high tensile steel at Trimmu and Kalabagh) further contributed to the difference in wear. At Islam, where cast iron rollers mated with cast iron tracks, the wear on the tracks was found to be minimal, understandably because of the similarity in the materials and because cast iron is less prone to corrosion compared to steel.

The wear on the track was found to be the most severe at Taunsa (although this barrage is the newest) presumably because the hardened stainless steel rollers ASTM A276, type 410 (hardened to 187-217 BHN) used in that case are harder than the cast iron used for the tracks; also the dissimilarity of the materials (stainless steel/cast iron) probably contributed to the corrosion of the track due to the electrolytic action. Although mild steel and high tensile steel are softer than cast iron, corroded surfaces of the mild steel/high tensile steel rollers probably contributed to the wear in the case of Panjnad, Trimmu and Kalabagh.

During site investigations, it was discovered that wear of the tracks and rollers was significantly affecting the operation of the gates because of frequent jamming. This is due to the roller assembly side plates making contact with the embedded cast iron groove portion on either side of the roller track instead of the rollers making contact with the roller track, and thus forcing the gate to slide instead of rolling on the track".

Restoration of the track at all barrages is urgently needed to restore smooth operation of the gates. The 1990 Harza Engineering company report "Rehabilitation of Gate Equipment at Various Barrages" recommended several alternate methods for possible restoration of the gate tracks. The Executive Engineer of the Mughalpura Workshop in Lahore took these recommendations studied them and developed a procedure, in consultation with Harza Engineers, that could be utilized to repair the gate tracks. To implement the procedure he and his staff developed a milling machine to enable the Irrigation Department to economically mill off the old tracks and then rebuild them. Another section of this report gives a detailed description of the machine and the process.

ENGINEERS RECOMMENDATIONS:

The various methods proposed for repairing the gate tracks referred to in the previous section are as follows;

a. Removal of the existing cast iron grooves and replacing them with identical grooves.

b. Cutting off and removal of the roller track portion of the existing grooves and replacing it with a bolted (bolted to the embedded parts so it can be readily replaced in the future) hardened stainless steel track.

c. Build-up of the worn portion of the existing track by welded overlay using nickel and nickel-ferrous welding rods and machining/grinding the overlay using a purpose made automatic tool (automatic so that a uniform surface can be obtained which is not possible if hand tools are used). Because the groove designs are different for different barrages, the tool design will have to vary from barrage to barrage.

d. Use of a suitable rebuilding compound to build-up worn portions of the tracks.

e. Grinding down the worn portion of the existing tracks to accommodate hardened stainless steel plates of adequate thickness. It is recommended that if this method of repair is adopted, identically dimensioned plates be used for build up of each track even if the wear on different tracks is different. The plates would be completely finished in the shop and attached to the existing cast iron tracks using an adhesive compound. The tracks would be drilled and tapped using a template which would also be used to locate the corresponding holes in the plates. Countersunk screws would be used to secure the plates after they are aligned with the portion of the track above the location of the replacement plate.

f. Build-up of the working portion of the existing track by welding or bolting a purpose made stainless steel plate dimensioned to suit the wear on the track. Because each track is worn differently, this alternative is not practical and therefore will not be considered further in this discussion.

For the record, it should be noted that hardened plates are necessary to prevent future fast wear of the track. This may not be possible because even if hardened plates are used to start with, the hardness will be compromised by the welding action. There is also a possibility of warping of the plates during welding. Mild steel plates present the additional problem of corrosion. During inspection it was discovered that

at Kalabagh (Jinnah) Barrage, mild steel plates were in fact welded to the track plates at some locations to correct the gate jamming problem. The welding was done on the face instead of at the sides (because access to the sides was not feasible) and there was a step between the new plate and the existing track because proper grinding could not be accomplished (grinding was done by hand). As expected the plates were corroded; because of that and because of the step, the plates presented a hinderance to the operation of the gate. On the day of the inspection, some of the new plates were being removed and the track restored to the as-worn condition because it was expected to result in better operation.

g. Use of spring loaded roller trains to compensate for the wear on the tracks and leaving the tracks as they are. Because of limited space available in the present grooves, design of steel springs or rubber springs is not feasible and therefore this alternative needs no further consideration.

LIMITATIONS:

Of the recommended solutions as presented in the 1990 HARZA Engineering report "Rehabilitation of Gate Equipment at Various Barrages" alternative "e". was selected by the Punjab Irrigation Department as the most feasible method. There were several difficulties or limitations which would have to be overcome before this method could be utilized.

a. What type of grinding machine could be utilized to carry out the necessary work to grind a recess to receive the new track plates.

b. The stainless steel plates that were recommended could prove to be extremely expensive. It would be more desirable to use a ductile cast iron. This also has limitations because this type of cast iron has never been produced in Pakistan.

c. All necessary materials such as a suitable adhesive, or other type of fasteners necessary to fasten the new track plate in place were not readily available in Pakistan.

d. Extreme time constraints have been established which limit the time that the work can be preformed to the once a year closure period.

SELECTED METHOD

GENERAL:

The Executive Engineer (XEN) for the Moghalpura Irrigation Workshop in Lahore, Mr. Mian M. Javaid and his staff, developed a prototype of a portable milling machine. Members of the ISM II, Harza advisory Team (The Workshop & Machinery Advisor, Mr. Thomas A. Liston, and The Punjab Provincial Advisor, Mr. Rue Boswell) observed the initial test run of the machine and felt that it had very definite potential. They strongly encouraged the XEN to pursue the development of the milling machine.

With the potential of this machine having been recognized the method of repair selected was method "e" with the following modifications; (1) using a milling machine instead of grinding, (2) use hardened cast iron replacement tracks instead of stainless steel and, (3) use machine screws to connect the replacement gate tracks to the milled surface instead of an adhesive compound.

DEVELOPMENT OF THE MILLING MACHINE:

A special machine to cut away the worn portion of the gate tracks at the various barrages was developed at the Moghalpura Workshop, PID, Punjab, A prototype machine was manufactured using only local materials and parts that were available and surplus at the workshop. The reason for constructing the machine was to test the theory of using a portable milling machine at each gate location to mill the worn portions of the existing gate roller tracks.

The concept of the machine is to cut or mill away the worn surface and provide a new surface that is on a vertical plane, perfectly parallel to the original track face to which a new track plate of machined cast iron could be attached.

To test this concept a "mock-up" section of a cast iron groove and roller track was constructed out of mild steel to the exact dimensions of the Trimmu Barrage. One face of the groove was then made from gray cast iron and shaped on the metal planer and then attached to the mock-up with screws. The cast iron plate was fabricated to the following dimensions; one inch thick, eight inches wide, and ten feet long. Prior to attaching the plate one side was milled so that the two surfaces between the plate and the groove mated together without the need of fillers. The counter sunk screws were attached by drilling and tapping the "mock-up" groove. The entire groove with plate attached was mounted in a masonry foundation that simulates the headworks of a barrage.

The machine was then mounted in the groove and adjusted to take a specific depth of cut on the cast iron 'ate. The round cutter head on the machine could accommodate up to eight cutter bits. The maximum depth of cut is one quarter inch for each pass with a total range of cut of one inch in increments of one/one-thousandth of an inch (.001"). The machine is powered by an electric motor that direct drives a transmission which provides for three different cutting head speeds.

In addition, the machine cutting head and drive mechanism moves in a vertical direction, the speed of this movement is in direct relation to the cutting head speed that has been selected. One should picture a milling apparatus where the milling head and drive mechanism traverses the material being milled instead of the material being fed into the milling machine. The entire cutter head and drive mechanism is mounted on an "I-Beam" which was manufactured in the workshop. These "I-Beams" are sized to fit and conform to the roller track grooves of the barrages. The entire machine was constructed to allow it to fit the grooves, it contains levelling bubbles and screw jacks to provide for accurate vertical and horizontal levelling. It also has been designed to cut in both upward and downward direction.

There were several difficulties encountered in the development of the machine. Throughout the entire development process the Harza Workshop and Equipment Specialist provided counsel and encouragement to the XEN. The final result was the development of a very effective portable milling machine that was successful in milling the gate tracks for sixteen gates of the Jinnah Barrage during the closure period of January-February 1991.

MATERIAL SELECTION AND PRODUCTION:

The inspection that was carried out in January 1990 and which has been referenced earlier in this report identified that part of the problem was due to the materials used in the original tracks and rollers. It has been noted that the cast iron gate track which is a part of the gate groove had been cast at three different locations and were of different hardness, also different types of metals were utilized such as stainless steel rollers on cast iron tracks.

In August 1990, the gate specialist for Harza Engineering Company, Mr. Chander K. Sehgal, was brought to Lahore to review the plan to carry out the gate repairs and to provide assistance in determining what materials to use. Mr. Sehgal had carried out the January 1990 barrage gate inspection and prepared the subsequent report. Mr. Sehgal also evaluated the portable milling machine and its operation on the "mock-up" track plate.

The result of Mr. Sehgal's visit and consultation was a decision by all concerned to fabricate the track plates from "Pearlitic Ductile Cast Iron" with a hardness range of 190 to 220 BHN. The rollers could be fabricated from grey cast iron with a hardness range of 150 to 170 BHN. Mr. Sehgal felt that the milling machine invented by Mr. Mian Javaid would work very well in resurfacing the track area. In addition it was agreed that the new plates could be attached by utilizing machine screws.

The Irrigation Workshops did not have the capability to produce the "Pearlitic Ductile Cast Iron", as a matter of fact this material had never been produced in Pakistan. A specialist in metallurgy, Mr. Jaseem Khalid Jaffri, was retained by Harza to research the existing commercial foundries in Pakistan to see if facilities existed where this material could be produced. Several foundries were located that had the necessary facilities. One was selected and awarded a contract, following the appropriate Pakistan Governmental procurement procedures, to fabricate unfinished gate track plates. The plates would be finished to precise dimensions at the Moghalpura Irrigation Workshop. The plates were fabricated at the Rastgar foundry in Islamabad under the surveillance of Mr. Jaffri, who was there to assure that the metal was produced to specifications and attained the desired hardness.

To manufacture roller track plates per ASTM 536-60 in grades 80-55-06 and 100-80-03 pertaining to pearlitic ductile iron, having good wear and hardness qualities, the following quality control procedures were developed.

1. Availability of foundry sands having 45 to 55 A.F.S fineness.
2. Sand drying facilities to obtain moulding sand with no moisture.
3. Sand binding material availability.
4. Use of sand slingers and other moulding equipment.
5. Manufacturing facilities to manufacture moulding boxes.
6. Sufficient raw materials and molten metal handling facilities.
7. Availability of proper raw materials, nodularizing materials and good quality inoculants.
8. Availability of a medium frequency furnace to raise the temperature to 1500 degree c.
9. Desulpherizing facilities in case of high sulphur content in the molten metal.
10. Laboratory facilities to analyze chemical constituents.
11. Micro-scope for determining the nodular count and pearlitic matrix.
12. Physical testing facilities to determine the hardness, tensile strength and yield strength.

Melting and casting was executed under the direct supervision of the Harza metallurgist at Rastgar foundry. The desired physical and metallurgical specifications were attained. It was an exceptional achievement. This material has high tensile strength and good hardness which meets ASTM A536-60 standards.

GATE TRACK REHABILITATION WORK AT JINNAH BARRAGE JAN 1, 1991 TO FEB 2, 1991.

HISTORY OF JINNAH BARRAGE:

The Jinnah Barrage near Kalabagh, Punjab was constructed from 1939 to 1943. The Barrage has a design discharge of 9.5 lacs cusecs (950,000); the length of the barrage is 3,781 feet, there are 56 gate bays 60 feet wide, and a 57th gate bay that is used as a lock for passage of boats. The barrage was originally built at a cost of 194 lacs of rupees (19,400,000). The materials and quantities used in the construction were; bricks 200 lacs; shingle (crushed stone) 78 lacs cu.ft; stone 77 lacs cu.ft. In 1982 an attempt was made to repair the gates so they could be operated manually. Mild steel plates in the form of a wedge were welded to the cast iron groove. These were welded on the face of the track as the sides were not visible because of the roller guards. This repair was not satisfactory, some of the replacement plates broke off and were washed away and those that remained were removed in 1989 and 1990 because they did not permit free movement of the gates. The overall condition of the gate tracks, roller trains, rocker assemblies were such that it was decided to attempt repair of a lasting nature during the 1990 - 1991 closure period. The closure was from Jan 1, 1991 to Feb 2, 1991.

PROCEDURES TO BE USED:

The work was to be done by two different groups as follows (1) Construction of coffer dams by placing sand filled bags upstream of the gates and grooves was undertaken by civil contractors arranged by the Barrage Division of the Irrigation Department. (2) Removal of roller trains, lifting of gates, machining of groove roller track, replacement of roller track, installation of roller trains and roller guards was to be done by the Moghalpura Irrigation Workshop staff. The entire operation was to be done under the supervision of the S.E Mechanical, Lahore, Mr. Abdul Jabbar Uppal, who had been appointed the Project Coordinator.

The original plan was to construct 20 milling machines, 10 right hand, 10 left hand, to do the actual resurfacing of the roller tracks in 32 gate bays; this meant a total of 64 roller tracks; cast sufficient replacement plates to replace the 64 worn roller tracks; replace the worn roller track with the new cast iron plates; repair or replace the roller trains, rocker assemblies and roller guards as necessary. Then lower and raise the gates to check that they are operating properly.

THE ACTUAL WORK ACTIVITIES:

a. Lowering and securing of ladders for access to the work area.
b. Lowering and placing of scaffolding cribs 2' X 2' X 6'; there were 2 each on either side of the gate bay to make it possible to work on the full length of the groove.
c. Removal of roller guards; welding of bracket for jack screw to hold the milling machine in place.
d. Lowering of the milling machine by mobile truck crane; positioning of the milling machine in the gate groove by chain block; leveling of the machine by screw jacks and securing the machine using jack screws and template guide.
e. Installing and adjusting carbide tipped tools and machining the groove from 11'-6" to 14' depending upon the wear that has occurred. The machine first made 1/8" cuts and then finished up with a 1/16" cut to a completed depth of 3/4".
f. Removing the brackets that were used to secure the milling machine by cutting with an acetylene torch. Lifting the machine out of the bay and transferring it to the next work location with the truck crane.
g. Measuring to determine the plate size, cutting the plates and drilling them for screws at the joint.
h. Painting the machined surface with white lead, placing the plates and holding them with screw jacks, drilling and tapping the screw holes.
i. Attaching the plates with machine screws after dipping screws in Magic Epoxy. The epoxy is to prevent the screws from loosening from vibration.
j. Installation of the roller guards.

EQUIPMENT TOOLS AND SUPPLIES UTILIZED

The following equipment tools and supplies were the main items used in performing the various tasks to complete the work.

1.	Vertical milling machine with counterweights, wire rope and pulley with mounting bracket. These machines were designed and fabricated at the Moghalpura Workshop Lahore	19 Each.
2.	Drilling machine for drilling cast iron track. Fabricated at M.I.W (This machine was not effective)	1 Each.
3.	Gas welding and cutting sets	3 Sets.
4.	Arc welding sets	3 Sets.
5.	Electric drills and tap sets	7 Sets.
6.	Generators 75 KVA (Denyo)	2 Each.
7.	Shaper, metal working (Beco)	1 Each.
8.	Drill press, floor model (Rockwell) 7.5 HP	1 Each.
9.	Mobile truck crane (P&H) 25 Ton	1 Each.
10.	Cargo trucks	4 Each.
11.	Pick-up truck	1 Each.
12.	Jeeps	3 Each.
13.	Bench vise	4 Each.
14.	Grinder, bench, 2 wheel	2 Each.

15.	Scaffolding cribs 6' X 2' X 2'	28 Each.
16.	Scaffolding cribs 4' X 2' X 2'	20 Each.
17.	Hand held disc grinders	2 Each.
18.	Bamboo ladders	20 Each.
19.	Chain falls (block and tackle)	16 Each.
20.	Tents, double fly	6 Each.
21.	Manila rope:	
	(a) 1" Diameter	500 Ft.
	(b) 1/2" Diameter	300 Ft.
	(c) 5/16" Diameter	400 Ft.
22.	Steel wire rope:	
	1/4" Diameter	500 Ft.
	1/2" Diameter	400 Ft.
23.	Nylon rope various sizes and diameters.	
24.	Miscellaneous items including:	
	(a) Control switches and boards	
	(b) Adjustable wrenches, oil cans, pry bars, hammers, chisels, cotton rags, etc.	
	(c) Electric cables and lighting sets.	

MATERIALS USED:

1.	Ductile cast iron replacement plates	42 Each.
2.	Flat head hex socket screws 1/2" X 2"	1000 Each.
3.	Roller guards	
	(a) 5' length	17 Each.
	(b) 10' length	4 Each.
4.	Rocker assemblies	3 Each.
5.	Miscellaneous items - white lead, Magic Epoxy steel, welding rods, gas cylinders, etc.	

WORK FORCE:

A group of 150 workshop technicians with different skills were transferred to the Jinnah barrage to perform the tasks which had to be carried out to complete the assignment. These workers were divided into teams so that they could work on several gates at the same time. These teams were composed of individuals with skills in various trade areas so that the work was done without interruption. These teams were supervised by a Foreman and a Sub-engineer.

SUPERVISION OF THE MECHANICAL WORK:

a.	Executive Engineer (XEN)	1
b.	Sub-Divisional Officers (SDO's)	2
c.	Overseer	2
d.	Foremen	4
e.	Consultants: Harza Engineers	4

AVERAGE TIME PER WORK UNIT:

While doing the work on the individual gate bays the average times needed to complete the required tasks was computed, they are:

a. Ladder placement and securing, lowering and placing scaffolding cribs 4 hours.
b. Roller guard removal and replacement for one bay - two gate tracks 24 hours.
c. Milling machine lowering, positioning, securing, levelling and removal 12 hours.
d. Machining of gate track 11' - 6" to 14' X 3/4" 15 to 20 hours.
e. Replacement plate installation (drill, tap and screw installation) 14 hours.
f. Roller train removal, replacement and lowering 8 hours.

EVALUATION OF ACTUAL WORK AT THE SITE:

A. COFFER DAM TO CLOSE THE BAYS:

The coffer dams constructed on the upstream side of the gate bays did not provide completely dry conditions for working on the gate tracks. Some of the bags were filled with clay and soil instead of sand; the coffer dam itself was not built according to the specifications that had been used to obtain NESPACK approval and to obtain the P.I.L for the work.

The bags were placed next to the gates and in such a manner that severe leaks developed, some of the soil and clay was washed from the bags creating severe leaking conditions and some of the bags were lost due to the very unstable condition of the coffer dam. At the suggestion of the Harza Engineers additional sand bags were used to strengthen the bund and reduce the amount of water passing through the bund. This also increased the safety of the structure.

Safety was a big consideration; on Jan 16,1991 the first working day for the mechanical group, the workers hesitated to go down to the river bed because of their fear of the coffer dam which they considered unstable. The XEN M.I.W, and the Harza Engineers were the first to go down to commence the work. The M.I.W staff after seeing them go down followed, the work progressed from that point.

B. ACCESS TO THE WORK SITE:

Because the coffer dams were not built to the original specifications, access to the work area was severely restricted. The only way to go down in the bays was by means of bamboo ladders. These were originally secured to the top structure by nylon ropes with the bottom resting on the coffer dam bags. However, the flexing of the ladder caused the ropes to rub on the sharp edges of the concrete, this would eventually cut the nylon creating a safety hazard and the possibility the users of the ladders might fall in the deep water.

It was suggested to the XEN M.I.W that manila rope be used for this purpose as it would resist the abrasive action of the concrete. In addition the rope should pass through and around the rungs of the ladder in such a manner to provide a safety hold for the ascending and descending persons. This proved to be quite effective and bolstered the confidence of the working staff that were constantly having to use the ladders. In addition, lengths of rope were strung along the sides of the span to provide a safety barrier for workers and material.

C. DIVISION OF LABOR AND TASKS:

During the first two days of work, Jan 16, and Jan 17, it was found that the deployment of staff was unsatisfactory; therefore, to improve the productive capacity of the workers the XEN, M.I.W was advised to form working groups to be utilized in the individual bays and special groups to remove roller guards, roller trains and rocker assemblies where necessary. These groups were made up of individuals having the different skills that were necessary to perform the tasks to complete the work. This arrangement proved very effective and was continued during the entire project.

D. INSTALLING AND LEVELING THE MACHINE:

The initial idea of drilling the masonry and using rawl plugs to clamp the machine in place proved unsatisfactory. The drills and drilling machines that were available would not cut the hard masonry. The tools to do this work had been ordered through AID on a PIO/C and did not arrive in time to be used. An alternative arrangement was devised which used screws that were on brackets, which in turn were welded to bolts in the groove. For horizontal adjustments a jack screw arrangement was welded to the machine girder and channel frame, a chain fall was used to positioning the machine in both horizontal and vertical planes. This proved very effective in holding the machine firm and plumb.

On Jan 19, Mr. Ghulam Qadir, Harza, designed and had fabricated a gauge from 1/2" X 1 1/2" angle iron. This eliminated any side wise movement of the tool chuck. This device reduced the machine leveling and adjusting time considerably.

The machine which was designed and fabricated by the XEN, M.I.W and his staff proved to be very effective and worked satisfactorily. It took from 15 to 20 hours to machine one track length, these were from 11'6" to 14' in length. The final cut was very smooth and required no fillers etc. to install the replacement track plates.

E. ANOMALIES ENCOUNTERED DURING THE TRACK REPAIR:

During the machining of both the left hand, and right hand side of the grooves on gates 17 and 18, it was found that the original groove had been repaired or built up from the bottom to a height of nine feet (9'). The repair or replacement plates were 3/4" thick; nine feet in length and held in place by 45, 3/8" diameter screws.

These plates were probably attached to the groove prior to the grooves installation in the barrage. These plates and the screws holding them severally affected the machining of the grooves; the screws and holes were responsible for frequent breaking of tool bits in the machine. The screws had to be ground as the machine would not cut them.

The fact that these plates were installed and have functioned for the life of the barrage supports the methodology for the gate track repair being adopted now.

F. THE ROLLER TRACKS:

Upon removal of the roller guards it was found that the wear on the lower portion of the roller track was greater than originally thought. This was especially visible from the side after the roller guard was removed. The wear extended to 14' rather than the 10' that the original inspection had revealed. It was, therefore, decided to mill the track to a height of 14'; the plates that were cast for use were 10' long, they were cut on a 65 degree angle and spliced to obtain the correct length. A metal shaper was taken to the work site to modify the plates to the correct size. The plates were originally drilled in the workshop for the screws that were to secure it to the groove; however, an additional member of holes had to be drilled because of the splice. White lead was applied to the milled off portion of the gate track where the new plate would be secured. The plate was then held in place, holes were drilled in the groove using the replacement plate as a template, the holes were tapped, the screws were dipped in steel epoxy and installed. The epoxy was used to keep the screws from loosening from vibration.

Two samples of the chips machined from the tracks were collected for chemical analysis to determine the material used in the grooves. However, Mr. J.K. Jaffery (Metallurgist) has stated the grooves are simple gray cast iron.

G. THE ROLLER TRAINS:

The roller trains which are 16 1/2 feet long were taken out and inspected; the following defects were noted:

1. The wear of the track and roller train extend almost the full length of the roller train or 14 1/2 feet. There are 17 working rollers in this length. (The number 1 or top roller acts as a hanger for the roller train).
2. Excessive play was found in all 17 rollers due to worn bushings and bearings in most of the roller trains in use.
3. The roller train side plates were overlapped and then welded, this has reduced the space in the groove. The side plates catch or drag when the gate is moved thus creating a great deal of friction and making it almost impossible to move the gates. This also puts a great deal of stress on the winches and wire ropes.
4. Most of the roller train side plate were found to be bent or out of shape due to the stresses being applied to them when an attempt was made to move the gates.

The plan was to repair the roller trains at site using spare parts available with the barrage division; however, the roller trains were in such poor condition that the spares that were available were soon exhausted. It was then necessary to use the old and damaged roller trains as replacements parts were not available.

It was obvious that the bushings and bearings for the existing roller trains had been made out of brass instead of bronze. The green deposits that were visible when the roller trains were removed, were the result of the oxidation of the brass, the flowing water washed these deposits away, thus, creating a space in the bushing which in time permitted the rollers to move side-wise. This made the roller eccentric, creating, in time, a ridge on one side. The most wear has occurred at the bottom of the groove and the lower end of the roller trains and rocker assembly; this has been caused by the hammering action on the track and roller train, again this is magnified by the hydrostatic load on the gate. The lower ends of the rocker assemblies, in some cases, have been broken by the same forces. The wear extends from the bottom of the groove to a height of 14 feet, this is through the entire length of the working rollers of the roller train. The various defects of the roller trains, i.e. bent side plates, different size rollers fitted in the same roller train, worn bearings, worn pins and overlapping side plates were all in evidence when gate No. 8 was lowered on Jan 25; this was after installation of the replacement track plate. The gate was jammed three feet above the sill because of these defects; the roller train was replaced with one that was assembled correctly and it operated smoothly with no obstructions noted.

H. WORK EXECUTION:

The pond level was lowered to a point that building of the coffer dam to plug the gate bays could be started on Jan 13. The first bays, numbers 16 and 17, were sealed off by the coffer dam on Jan 15. Labor and material to commence the work was transferred to the site on Jan 14; work of repairing the gate tracks for bays 16 and 17 commenced on Jan 16. The first three days, Jan 16 through 18, were spent in familiarizing the entire work force with the procedures and methods to be used to repair the gate tracks and components of the gates. The gates were lifted, the roller trains were removed; the nuts holding the roller guards were removed; the roller guards were pried away from the structure; ropes were attached to the roller guards and they were lowered. The machines for cutting the worn track were lowered into place, they were plumbed, the replacement plates were cut and drilled to fit to the height of 14 feet instead of the planned 10 feet. A mobile crane was used to lower the machine and a chain block was used to position the machine. The position of the clamps to hold the machine were marked, the machine was removed from the groove and holes were to be drilled for the rawl plugs to be fixed in the masonry piers to hold the machine firm while it was in operation cutting the worn roller track. However, when the drilling machine, which had been manufactured at M.I.W, was lowered it was found the masonry of the piers was very hard and could not be drilled. A great deal of time was spent exploring alternative methods of holding the machine; finally through trial and error, a system was devised that required welding a bracket to the groove bolts, the machine was then clamped in place with screws that were in the brackets. In addition a jacking arrangement was welded to the girder and channel of the machine, this along with the chain block was used for positioning the machine. This proved to be very effective. A gauge, which was devised by a Harza Engineer, was used in levelling the machine, this also helped to keep the machine in alignment after installation and reduced, by about two thirds, the amount of time needed to level the machine.

The machining process for one groove after setting the machine, took approximately 15 hours. The initial cut was 1/16", additional cuts of 1/8" were made until a depth of 3/4" was reached. The length of the entire cut was from 11'6" to 14 feet this depended upon the wear on the gate track. Upon completion of the machining, the machine was removed from the groove and the entire machined portion of the roller track was coated with white lead. The two replacement plates, which had been cut on 65 degree angles, where they joined, were clamped in place and they were used as templates for drilling the holes in the base plate. The drilling was done with hand held machines using a lever arrangement to obtain enough pressure to drill the base plate; the base plate was then tapped for the counter sunk screws; the screws were dipped in magic epoxy steel and tightened. Upon completion of the installation of the replacement roller track, on both sides of the bay, the roller guards and roller trains were installed and the gates were then lowered and raised for operational testing.

Initially the complete repair of one gate bay took seven days; however, this time was reduced gradually until one bay took five days. Gates 8 and 16 were completed and tested on Jan 23. The remaining 14 bays that were repaired were completed on February 3. Although, the M.I.W mechanical Staff had the material and staff to complete an additional four gates, the Barrage Division was unable to arrange coffer dams for them.

I. PROBLEMS ENCOUNTERED:

a. The original planning called for drilling 1" holes in the masonry of the piers for rawl plugs to be used to secure the milling machine. This was not possible since the tools available would not drill the masonry. The drilling machine designed and fabricated at M.I.W, was unsatisfactory, it broke teeth on the ratchet mechanism that applied drilling pressure. An entirely different scheme for holding the machine was developed and this proved to be satisfactory. The failure of the drilling machine made it necessary to arrange for and obtain portable hand drilling machines to complete this work. It took approximately three days to overcome these initial problems and actually begin the work, this was on Jan 19,1991.

b. The "brinelling" (hardening by hammering) effect of the rollers on the roller track along with the holes for screws and broken screws and taps where the tracks had been repaired previously (gates 17 and 18) caused excessive breaking of the carbide tips; this resulted in having to stop the machines frequently to refit bits; in addition, the hardened track surface dulled the bits and they had to be sharpened more frequently, thus delaying the machining of the track surface.

c. The extraordinarily hard roller track required special drill bits and taps for making the screw holes for securing the replacement roller track. These special tools had to be obtained in Lahore and then sent to the site.

d. The lack of planning to have consumable supplies and hand tools, such as, adjustable wrenches, chain blocks, ladders, wooden blocks, steel wedges, grinding wheels wire rope with cable clamps, 1/4" and 1/2" hand drills, nuts and spring lock washers for the roller guards also added to the delay of the work. NESPAK during the review of the estimates for the work had removed items completely or reduced quantities from the above list. This delayed the work unnecessarily.

e. The original replacement plates were cast 10 feet long; however, when the roller tracks were exposed by lifting the gates and removing the roller trains and guards, it revealed the wear from 11'6" to 14 feet. The replacement plates were cut on a 65 degree angle to extend their length to the required size by using two pieces. The cutting was done by a shaper that was brought to the work site from M.I.W in Lahore.

f. The welding machine malfunctioned and repairs had to be made before it could be used to continue the work. There was no back-up machine available. This again delayed the work.

g. The coffer dam was originally to be constructed so that 8 gate bays would be closed together as a unit; this would permit the workers to move from one bay to another, transfer tools and supplies, etc. However, only 4 consecutive gates were closed by the coffer dam; this spread the work over the entire length of the barrage, thus increasing the time for supervision, transfer of tools, supplies, etc. Also, the coffer dam was constructed between the piers and not at the nose as originally specified. This created several problems but the worst was the fact that the workers and their tools could not be moved readily from one bay to another.

h. The assignment of the labor force was not done on a systematic basis at the start of the work. Workers went to work where they wanted to or sat around and did nothing. At the suggestion of Harza Engineer Javaid Awan, teams were formed with workers skilled in the various trades that were needed to complete the work. These teams were assigned various tasks and in a sense were in competition with each other.
This system functioned ve y well and was responsible in a large degree for making it possible to complete as many gates as were done. The moral support and assistance provided by the four Harza Engineers was a great help to the Executive Engineer, M.I.W and helped him to gain the confidence and support of the workers assigned to the job.

GENERAL CONDITION OF THE MECHANICAL COMPONENTS OF THE BARRAGE:

A. GATES:-

The exact condition of the structural members and the skin plates of the gates could not be ascertained visually. It would be necessary to scrape and sand blast the components to determine if painting is the only thing that needs to be done. During the closure a thin cost of bitumen in oil was being applied to the gates, this was done without ascertaining the structural integrity of the gate itself.

B. ROCKER ASSEMBLIES:-

Damage has occurred on the lower portion of the rocker assemblies for the following gates; No.1-L; No.3-R; No.4-L&R; No.5-R; No.18-L; No.26-R; No.29-L; No.36-R; No.38-L&R; No.44-R; No.54-L&R; and No.56-L.
Welding repairs have been made to the lower portion of the following rocker assemblies; gate No.2-L; No.14-R&L; No.18-L; No.24-R&L; No.25 R&L; No.26-L and No.31-R.

C. ROLLER GUARDS:-

Gate No.11-R&L and gate No.9-L were found to have damaged roller guards, these were replaced.

D. ROLLER TRAINS:-

The roller trains of all the gates were found to be worn out. The bushings or bearings have excessive play and some are missing completely. The sides of the roller trains in some instances are bent and overlapped side plates have been welded in place, this causes the roller trains to stick thus making the gates very difficult to operate.

E. STAUNCHING PLATES:-

The staunching plates and brackets on some of the gates are worn out or completely missing.

F. CREST AND SILL:-

On gate No.18 the crest and sill is completely worn out. On others they are damaged and need repair.

G. WINCHES AND GEARING:-

The pinion gears of the winch mechanisms have shifted laterally and are rubbing the winch drum; on gate No.8 this is damaging the drum lugs on the pinion side, it also increases the effort needed to raise the gate.

H. RECOMMENDATIONS:-

The work that was done on the 16 gates at Jinnah barrage during the 1990-91 closure has resulted in smooth and normal operation of these gates. The method used for repair of the roller track has proved to be very successful and should be utilized to repair the gate tracks of the remaining gate bays of the barrage. Repair of the roller trains and the rocker assemblies will also contribute to easing the operation of the gates.

OBSERVATIONS REGARDING THE WORK:

A. The following are general suggestions that are made for all the barrages in Punjab:

a. The M.I.W staff has gained a great deal of experience and confidence, this will enable them to continue the repair of this and additional barrages. During the next closure the staff of the Bhalwal workshop along with M.I.W should be jointly utilized to execute additional repairs. This will enhance the PIDs ability to carry on these repairs for all barrages and headworks.

b. A complete and thorough inspection of the various barrages should be carried out jointly by the two workshops. Special attention should be given to the superstructures, the gate hoisting mechanisms and wire ropes. Any repairs or action to be taken as a result of these inspections should be decided upon and funding provided to give the workshops ample time to plan and prepare for the work to be done.

c. A mechanical means for stopping the water flow should be developed. The building of coffer dams with earth and sand filled bags is expensive and time consuming. These coffer dams also present a continuing hazard for the working staff. A stop log system should be considered for this purpose.

B. The following suggestions are made for Jinnah barrage:

a. All gates should be scraped and sandblasted the structural members and skin plates inspected for structural integrity and the skin plates should be measured to determine thickness. Necessary repairs should be made and the gates then painted with a good quantity coaltar epoxy paint.

b. Roller trains should all be replaced during the next closure. The old roller trains should be repaired and then stored for future use.

c. The rocker assemblies should be cleaned lubricated and if damaged or broken should be replaced. At least 20% of the rocker assemblies need to be replaced.

d. The wire ropes need to be inspected cleaned and lubricated regularly. Frayed or damaged wire rope should be replaced.

e. Approximately six right and six left roller guards should be on hand to be utilized for replacement of damaged roller guards.

f. The winches and gearing mechanisms need to be inspected for defects on a regular basis. The mountings should be kept tight, the chains for counter weights should be in place, missing and damaged plates should be replaced, adjustment for all winch drum pinions need immediate attention, lubrication of winches should be done on a systematic basis. One foreman or supervisor should make a weekly inspection of the superstructure and the hoisting mechanisms and order repairs or service where necessary. Winch operators should be trained to recognize the need for adjustments or repairs and they should be encouraged to notify the responsible officer.

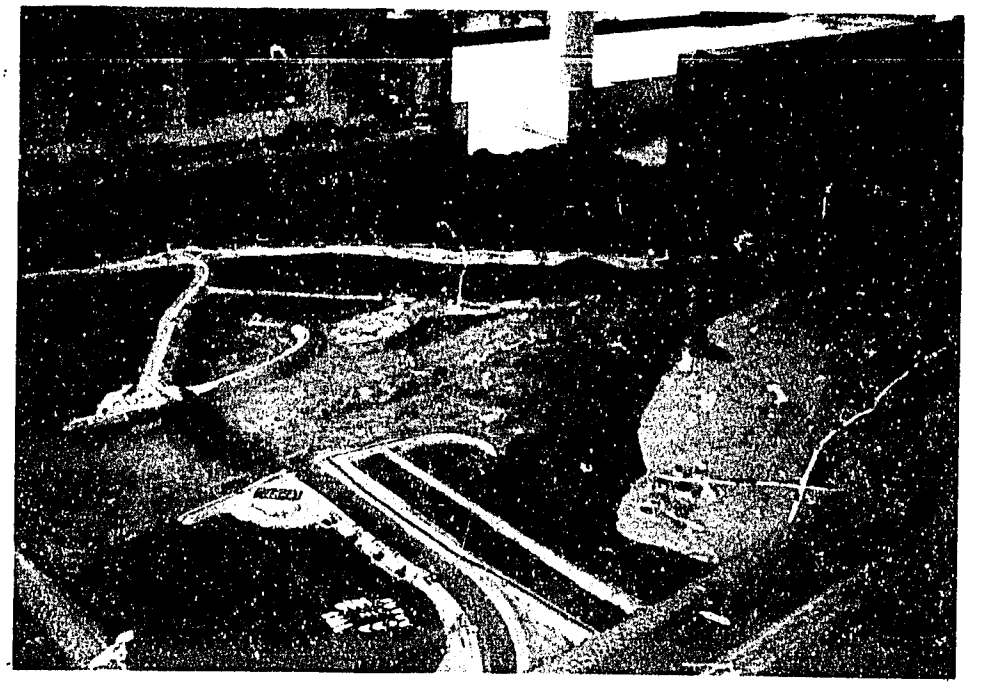
g. Staunching plates: The worn out plates and brackets need to be replaced. Proper movement of all staunching plates needs to be checked and adjusted or repaired if possible.

h. Crest and sill: The crest and sill of each bay should be inspected and repairs made where needed, this can only be done during the closure and when a coffer dam is in place.

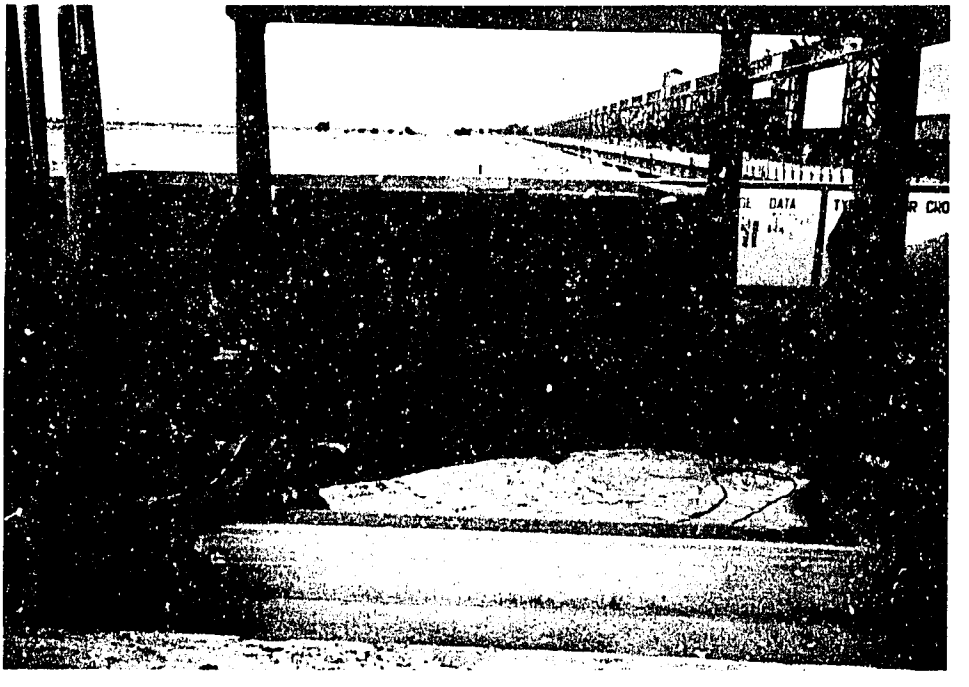
SUGGESTED ORGANIZATIONAL RESTRUCTURING:-

Looking to the future and at the magnitude of the work that will have to be done to rehabilitate the 13 barrages and the many headworks in Punjab, it would seem to be desirable to establish an independent Barrage Mechanical Division along the same lines as is the practice in Sind. This division should be responsible for the regular inspection of the mechanical structures of the barrages and headworks, establishing priorities, preparation of estimates, coordination with the civil and workshop divisions for scheduling and execution of work and then monitor the results of repaired or replaced components. This is an idea which could be transformed into a detailed proposal if PID Punjab exhibits any interest in this suggestion.

The way the present organization functions, the mechanical sub-engineers are responsible for the maintenance of mechanical structures at the various barrages and headworks. At a minimum, in the present organization at least one assistant engineer mechanical should be appointed and made responsible for the proper and continuing maintenance of the enormous mechanical component at each barrage.



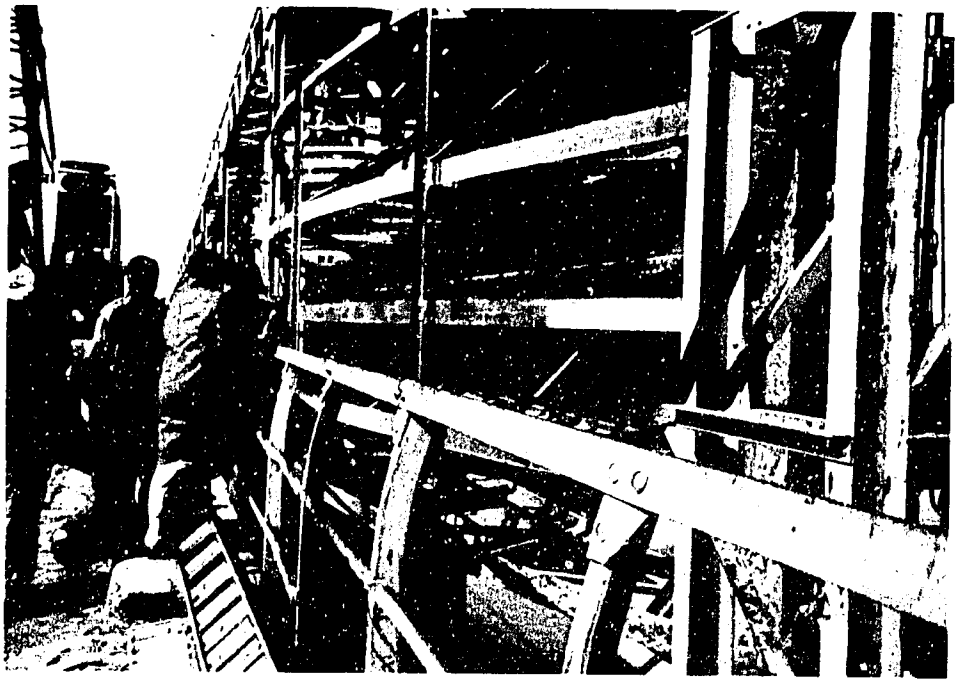
Views of the model of Jinnah Barrage located on the left bank of the Barrage. (Jan 1991).



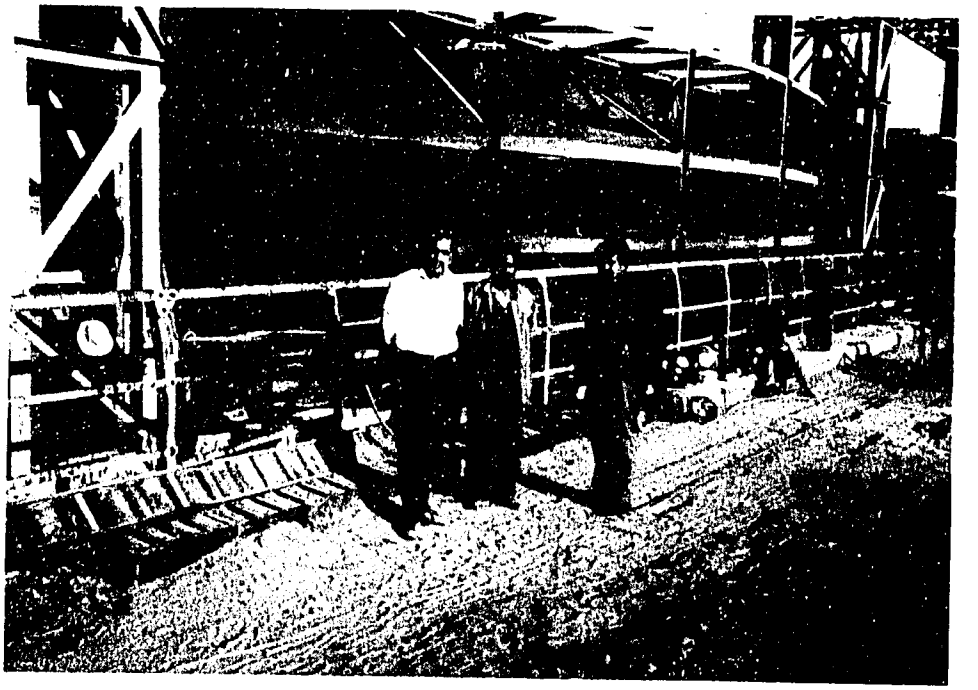
The Executive Engineer, M.I.W, Mian M. Javaid, Equipment Advisor, Thomas A. Liston and Equipment Engineer, Javaid Awan visit Jinnah barrage to commence planning for repair of gate tracks. (June 1990).

Inspecting Jinnah Barrage gates and mechanical apparatus to assess repair possibilities. (June 1990).

Inspecting the roller trains, rocker assembly while the gate is being lowered; Mr. Obaidullah, Mian Javaid and Liston.
(Jan 1991).



Harza Engineers Bolbolan, Qadir and Javaid Awan discussing project activities with XEN, M.I.W. (Jan 1991).

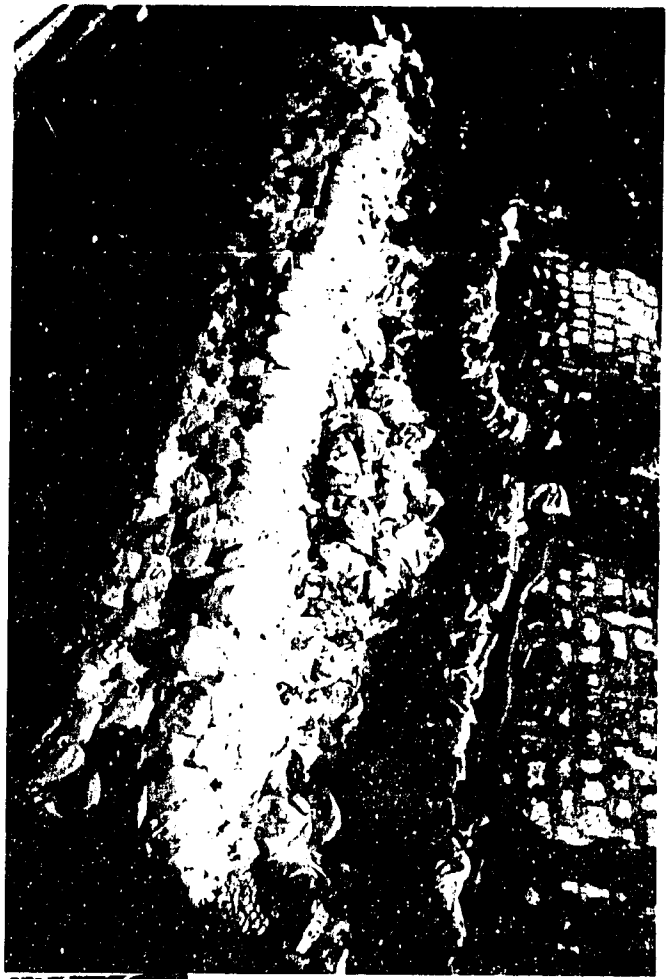


Harza Engineers Hameed, Qadir and Bolbolan in front of a raised gate. (Jan 1991).

The coffer dam is in place, ladder for access is secured, cribbing being placed for installation of the milling machine. (Jan 1991).

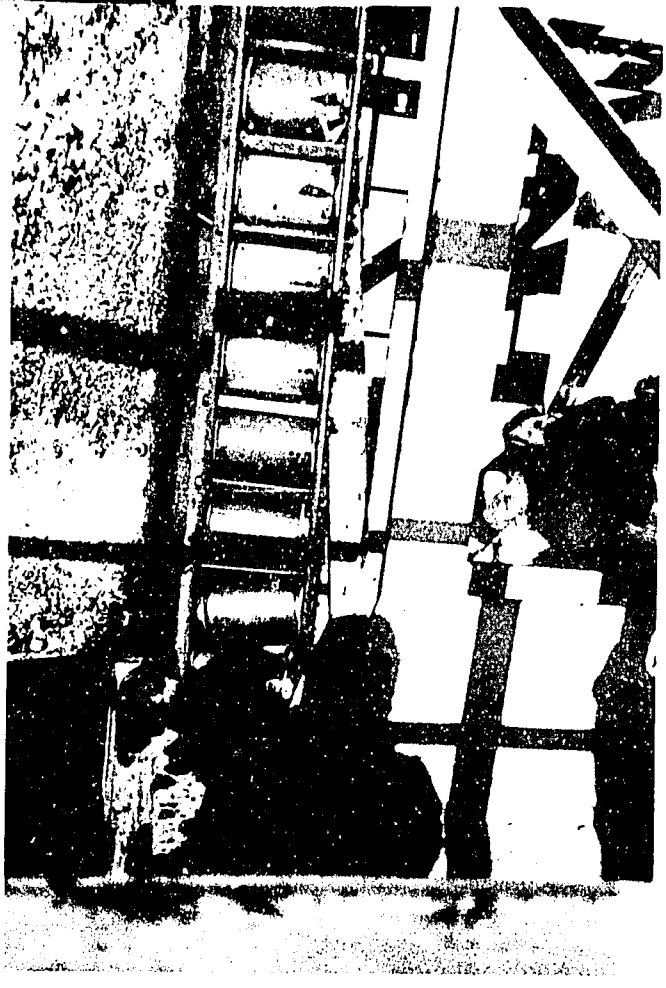
View of the coffer dam from above, the bottom portion of the gate can be seen at the top of the picture. Note: No safety support for the gate. (Jan 1991).

View of the coffer dam and a portion of the repaired floor of the gate bays; note small diversions to protect masonry work.
(Jan 1991).

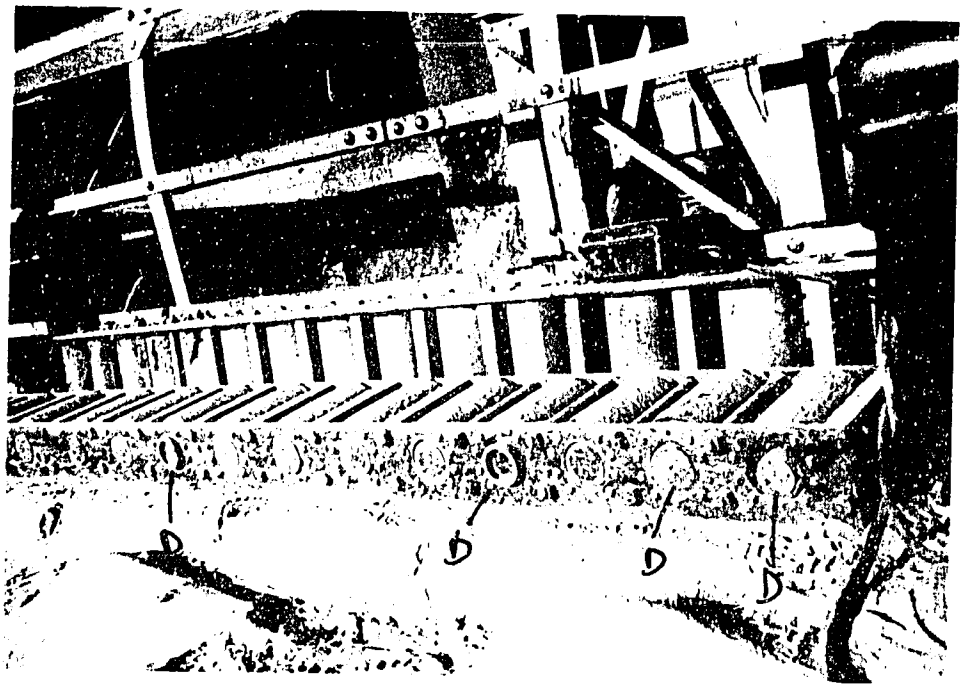


Full view of work site and workers.
(Jan 1991).

A roller train that has been removed and is being inspected by the barrage maintenance crew. (Jan 1991).

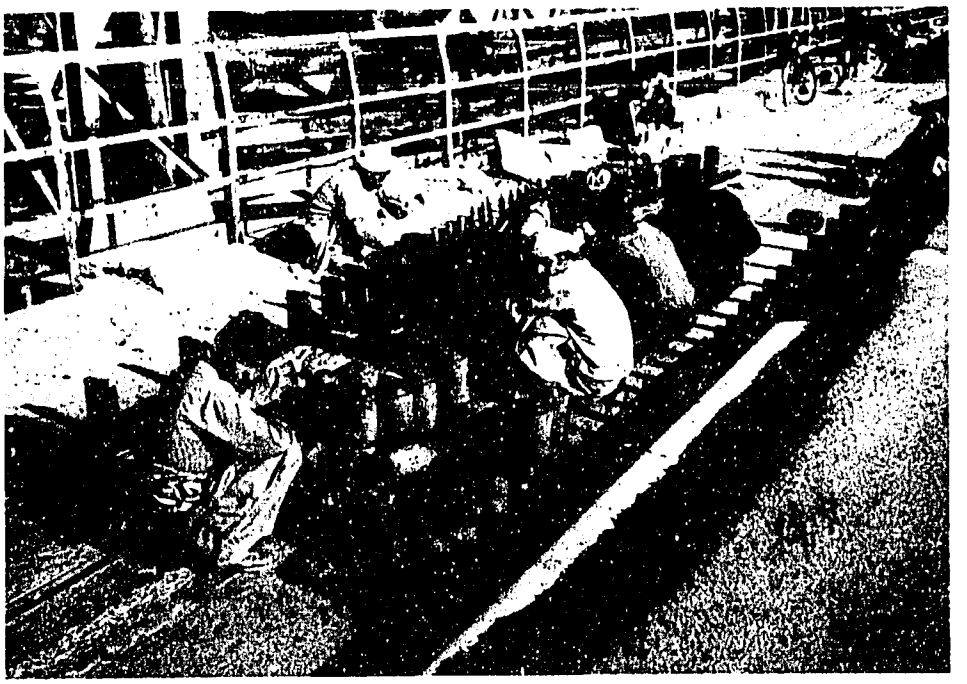


A badly damaged roller train that has been removed. This roller train has made the gate very difficult to operate and in turn may damage the hoisting mechanism. (Jan 1991).

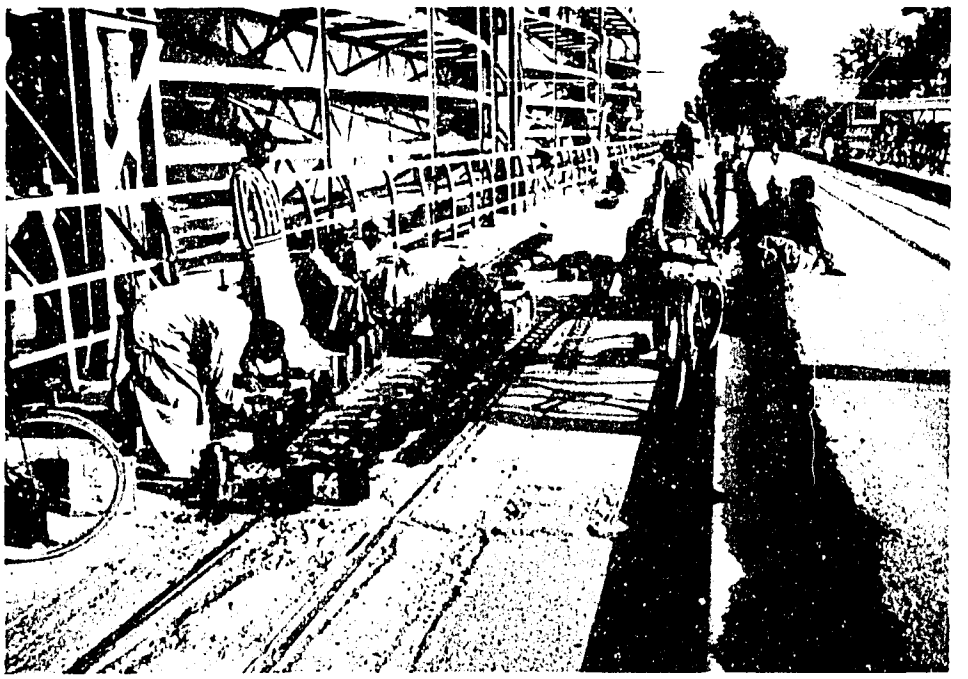


Roller trains that have been removed. Loose, missing and defective bushings are shown at "D". (Jan 1991).

Defective roller trains which need to be replaced when the gates are put back in service. (Jan 1991).

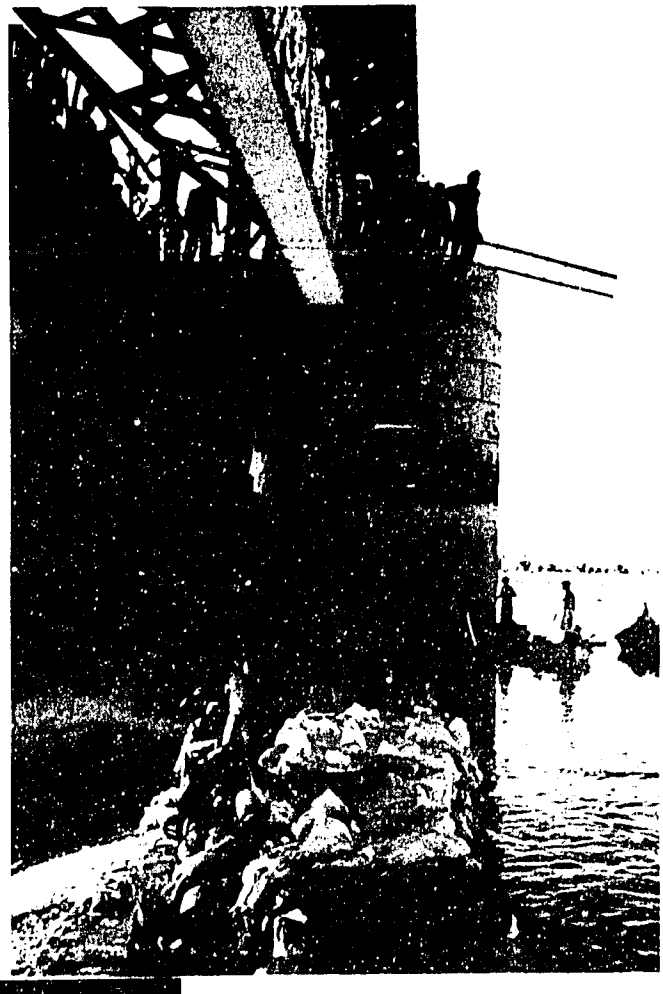


Barrage maintenance workers cleaning, repairing and lubricating roller trains. Working conditions are not ideal, dust and sand is a problem. (Jan 1991).



Barrage maintenance staff reassembling roller trains for installation between gates and roller track. The diameter of the rollers was not checked to make certain all were the same. (Jan 1991).

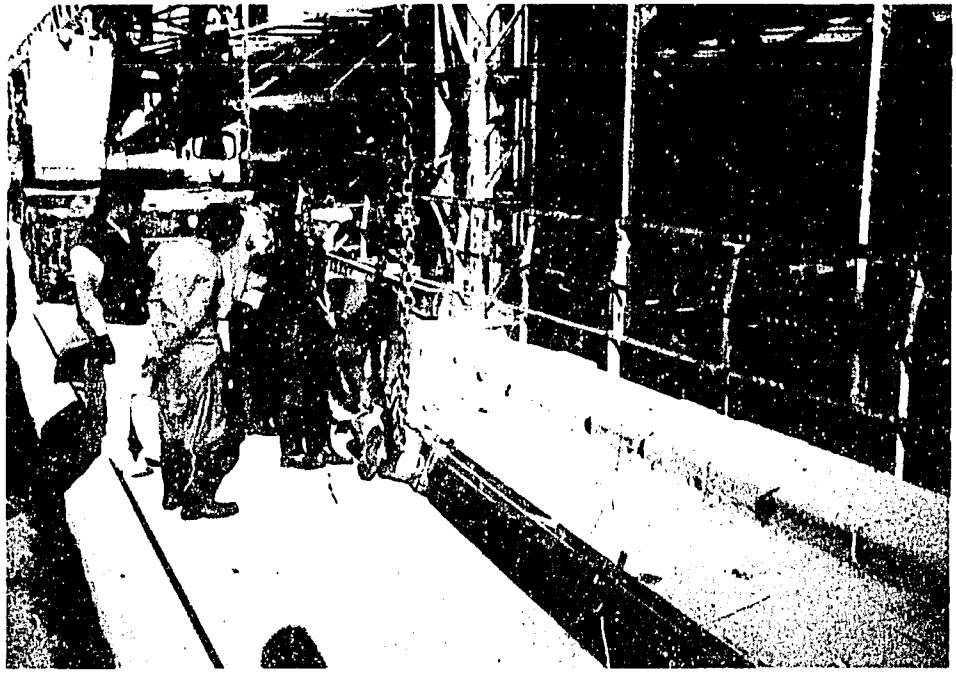
Ladders being placed and secured for access to work site, also roller guards are being removed so milling machine can be installed. Boats are being used to deliver sand bags for construction of the coffer dam. (Jan 1991).



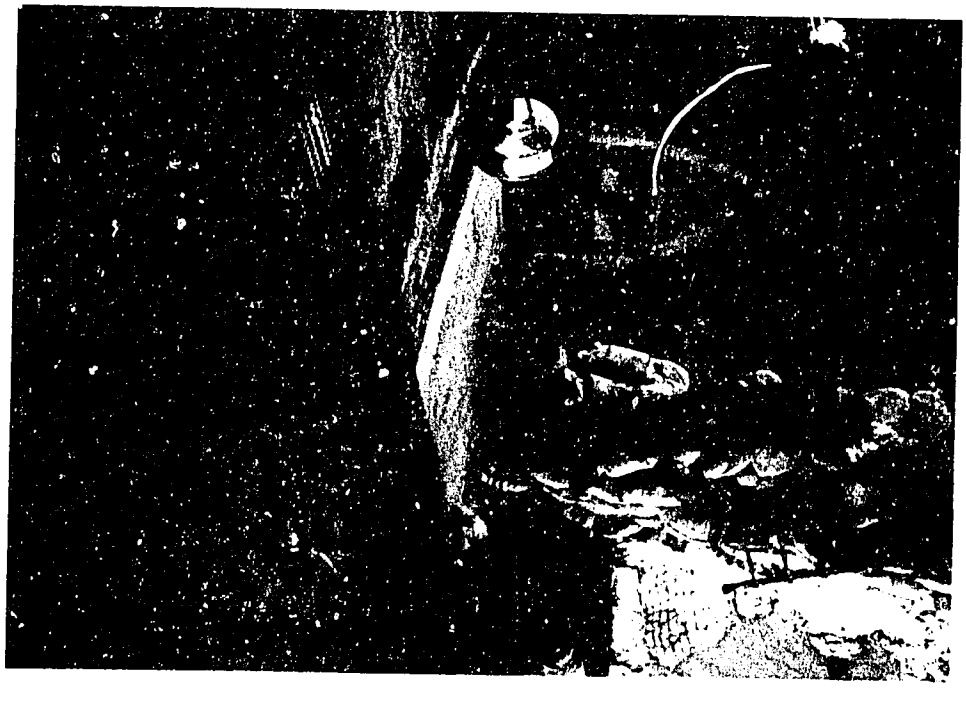
Removal of roller guard, prior to installation of the milling machine.
(Jan 1991).

Removed roller guard lying on the coffer dam. XEN Mechanical M.I.W inspecting the work while one worker determines the extent of wear on the roller track. (Jan 1991).

Upper portion of replacement plate is clearly visible.

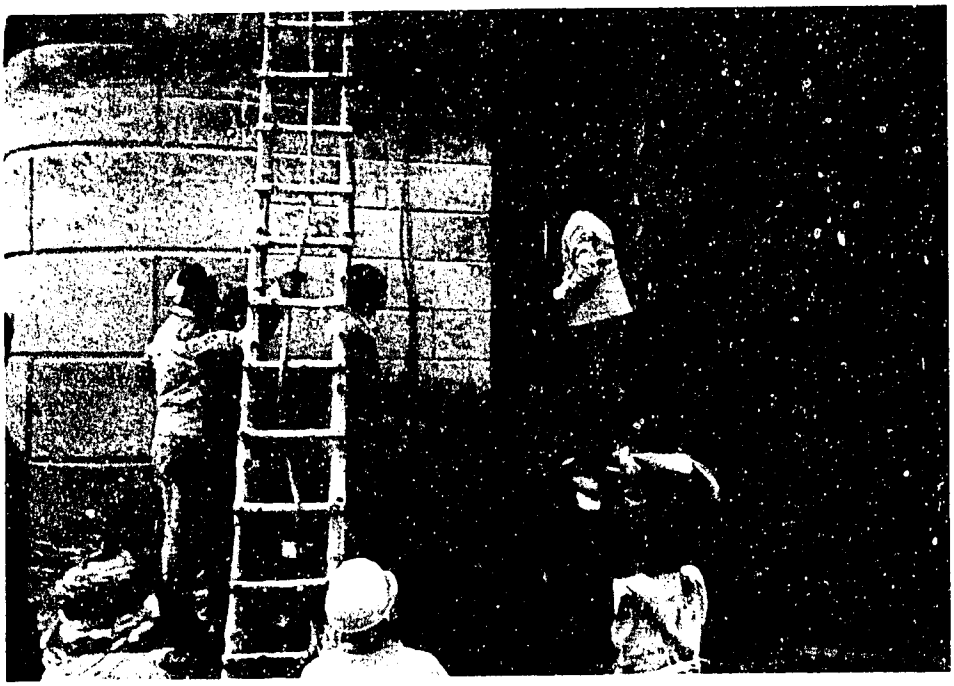


The Milling machine being prepared for lowering and installation in the groove. Javaid Awan of Harza Engineers checks progress. (Jan 1991).

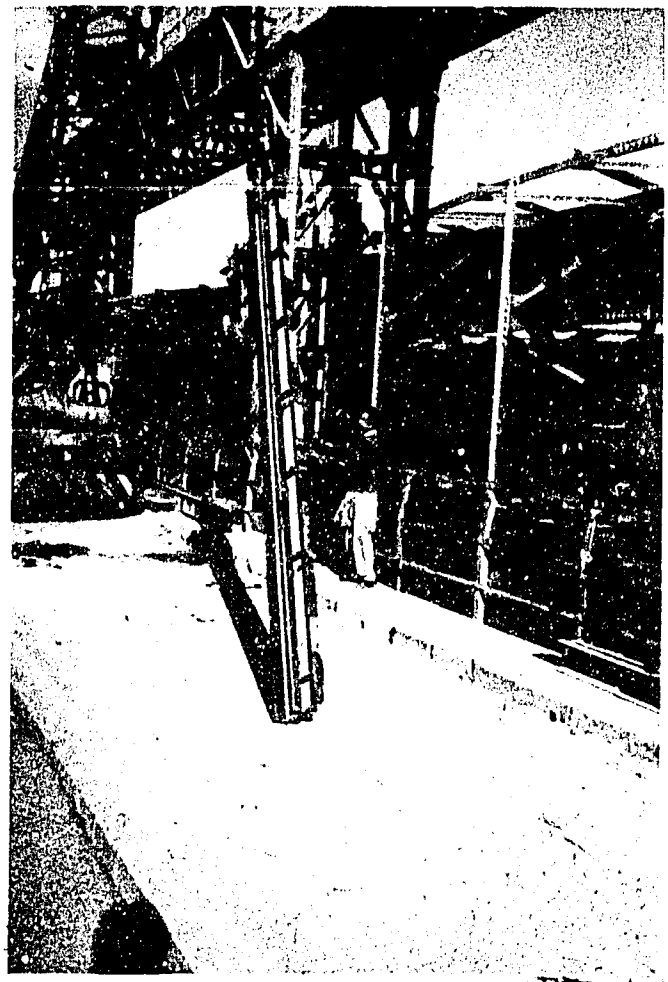


Machine is being lowered, roller guards that have been removed are on top of sand bags. Boat was used for building coffer dam and transport between bays.

The XEN, MIW and Harza engineers checking the installation of the Milling Machine.



Mr. Uppal, S.E. and XEN, MIW observing the Milling Machine as it is cutting the worn roller track in the gate groove.



Major Hameed, Harza Engineer signals the crane operator as he is preparing to lower the Milling Machine into the groove of bay No. 9.

Workers preparing groove for installation of Milling Machine.

The Milling Machine is cutting the extreme bottom of the gate track.

The Milling Machine is being removed from the groove. A broken roller guard and a replacement are visible.

The XEN, MIW and the Harza engineers are pleased with the successful operation of the Milling Machine.

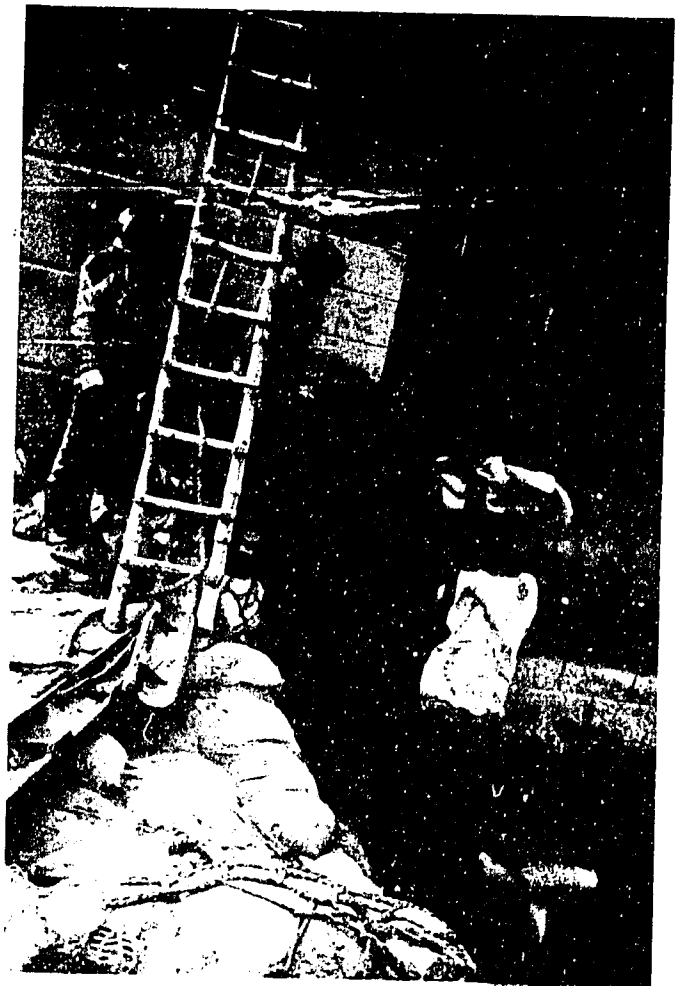
The XEN, MIW measuring the depth of the final cut.

The machine operator is making the final cut.

The first pass of the machine only cuts at the top where the wear on the track is not so great.

Machinists operating the Milling Machine under the supervision of the SDO, M.I.W.

"L" clamp being welded to bolt in gate groove to secure Milling Machine.



The S.E. Mechanical checking the progress of the work.

The final cut of the machine leaves a smooth surface the full length of the worn gate roller track.

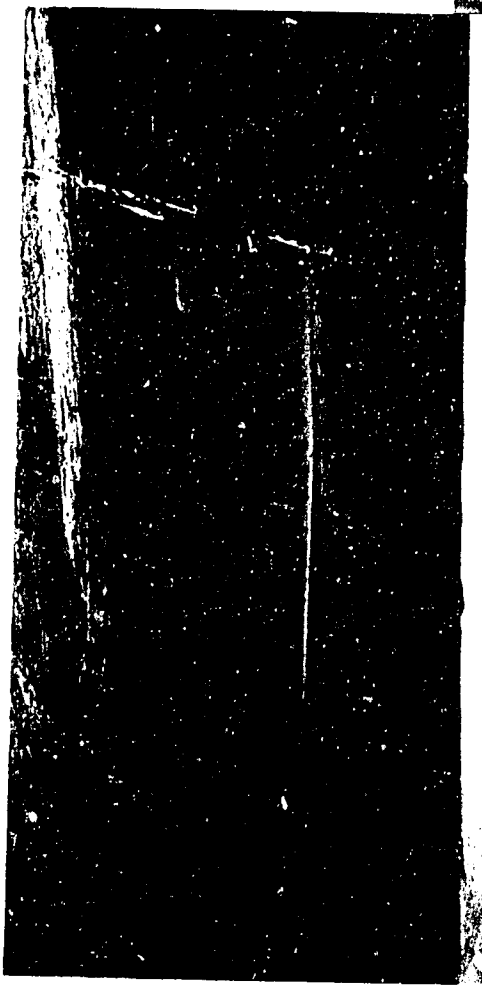
The XEN MIW supervising the removal of the milling machine upon completion of the work.

The feed gear on the Milling Machine is being replaced in bay No. 8. Spare parts were manufactured and on hand so the work would not be delayed.

The roller track prior to machining.

Screws being tightened in replacement plate.

View of the final cut prior to the removal of the machine.



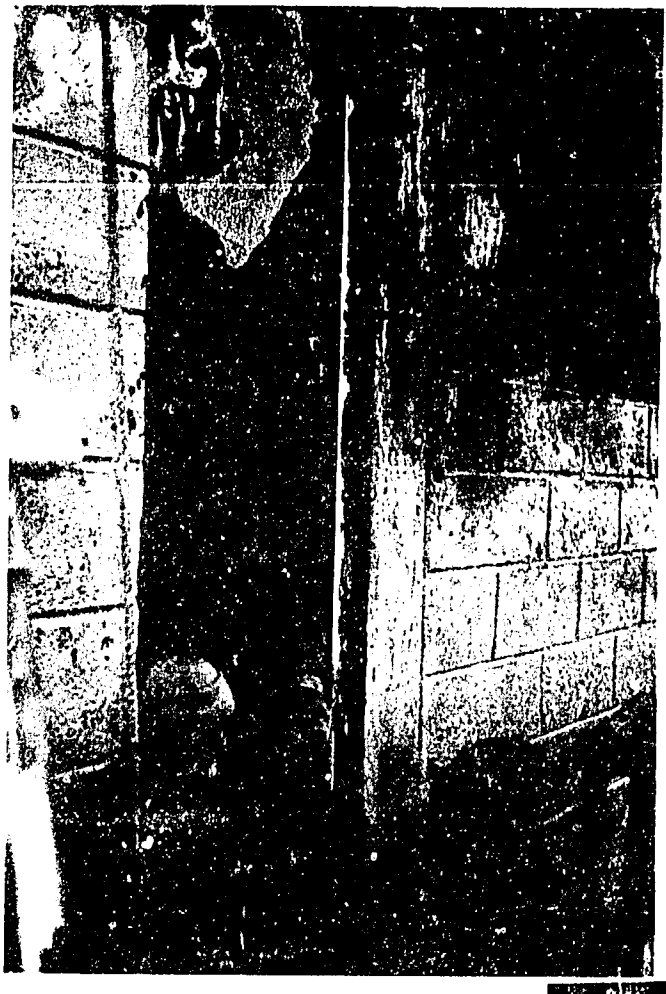
The roller track after machining, bolts for roller guard are clearly visible.

Cutting the replacement plate on an angle to extend the length. This operation being observed by Harza engineer's Javaid and Qadir.

Cutting replacement plates. Three plates were used in each bay instead of two.

White lead being applied prior to attaching replacement plate.

Drilling and threading the groove for attaching the replacement plate.

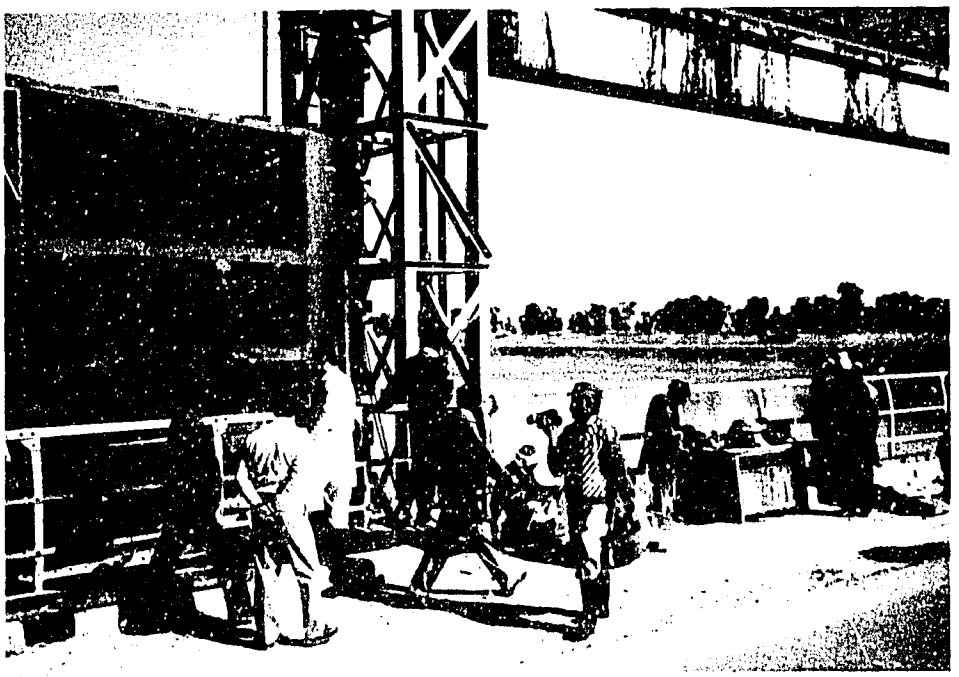


Full view of replacement plate in place with splice showing.

Jack used to hold replacement plate while it is secured with screws.

Roller guards being replaced.

Final tightening of roller guard bolts.



S.E. Mechanical and XEN, MIW inspecting work along with Harza Engineers.