FAILURE OF A GATE OF SUKKUR BARRAGE, A LESSON FOR THE FUTURE.

BY
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5000 years of irrigation in Sindh.

In order to understand functions of Sukkur Barrage and from that point the two other barrages namely, Guddu and Kotri, we have to understand the history of irrigation in Sindh. The Indus Valley civilization was an outcome of irrigation which had started in its rudimentary form at the beginning of Amrian times (3500 BC). As irrigation covered more and more area, the civilization reached its climax between 2300 to 1650 BC and is presently known as Mohenjo Daro or Harappa Culture in Sindh.

Every time the Indus changed its course irrigation system was destroyed resulting into political upheaval and change of dynasty.

This culture abruptly declined as the river Indus changed its course, deserting the central alluvial planes, of Sindh and swinging too far, either to the east or to the west of the plains, wherefrom water could not reach the irrigated tracts as those were at higher level than the new bed of the river. The civilization as a consequence declined and Sindh almost turned to a desert between 1650 to 900 BC. Archaeologically this period is called Jhukar and Jhangar culture and lately has been assigned the name of the Declining Indus Culture. Rough estimate of population of Sindh is 250,000 souls from 3000 to 2700 BC i.e., “Mid Kot Dijjian Times”. It must have reached at least 5 to 6 lacs by the time Mohenjo Daro reached its maturity in about 2200 to 2000 BC.

Every successful dynasty concentrated on upkeep of irrigation system.

Information on Sindh’s history, so far collected reveals that the prosperity of Indus civilization, Rai, Brahman, Habari, Soomra and Samma dynasties must have been the consequence of better management of irrigation and agriculture. Likewise the fall of these dynasties most probably was on account of changes in the course of river Indus. The short-lived prosperous rule of Kalhoras was also an outcome of well managed irrigational system and in fact could only be equaled by the British efforts after 50 years of their long struggle with the Indus and its behavior. Kalhora dynasty declined immediately after the change of course of the river Indus in 1758. The consequences were drastic.

Alexander's historians witness recent destruction of irrigation system by the river Indus.

It appears that between 950 and 519 BC irrigational system was again revived in Sindh. The river Indus that time was flowing many miles east of the present course and both of its banks were under cultivation. The western limit of irrigated area was probably the same as the present course of river Indus. The area below Sukkur and down to present Hyderabad was known as Brahmanka andits main town was also named as such. In time it changed to Brahmanabad. Between 519 BC and 400 BC Sindh was ruled by Achaemenian Persians. The irrigation system had been so well managed that Sindh (below Multan) paid 36 lac tankas in gold as tax to the Persian Emperor. Just before Alexander the Greats invasion of Sindh (325 BC), the river Indus had changed its course to the east with the result that his historians saw the country of Oxycanus (Nawabshah and Khairpur districts) in ruins. The river had swung too Far East in a depression wherefrom water could not reach the irrigated land.

There are different estimates as to the population and area under cultivation in Sindh then. The figure according to different estimates varies between 5 and 10 lac people and possibly 4 to 7 lac acres were under irrigated agriculture.

Improvements in irrigation responsible for flourishing trade with Roman Empire 1000 BC – 100 AD.

Mauryans ruled Sindh between 323 and 148 BC. The agriculture and irrigation system suffered heavily under later Mauryans on account of high burden of taxes and possibly mismanagement of irrigational works. Mauryans were replaced by Bactrian Greeks (184 to 70 BC) and the latter were replaced by Scythians (70 BC to 45 AD) and Parthians (46 to 78 AD). The irrigation system seems to have been reorganized during that period as Sindh was exporting lac-dye, spices, red pepper, sugar, indigo, cotton linen, wood, rice and sorghum to the Roman Empire through its port of Barbarican (Bhanbhore). Nothing is known about irrigation during Kushans (78 to 175 AD) and Sassanians (283 to 356 AD) but irrigation system seems to be well-managed by Vahlikas (356 to 415 AD).

Changes in the course of the river Indus and decline in irrigation system makes easy conquest of Sindh by Muhammad Bin Qasim.

The great improvement in the irrigation system came from Vahlikas onwards and under Rais (499 to 641 AD), and Brahmans (641 to 712 AD). The river Indus seems to have changed its course just before 700 AD causing a migration of the Kathia tribes of Sindh to new area south of Kutch, to which they gave their name Kathiawar. The whole irrigated structure of lower Sindh seems to have been destroyed and the area depopulated as Arab troops under Muhammad Bin Qasim had to march through the area without any opposition; the forts having been opened without any resistance. Under Umayyad and

Abbasid governors of Sindh (711 to 749 AD and 751 to 854 AD respectively), irrigation system could not be managed and the destruction caused by change of course of the river around 700 BC was not fully recouped resulting in continuous turmoil, uprising and lawlessness. It was Habarian (854 to 1011 AD), the local Arab dynasty who managed irrigation system very well. The population increased and trade flourished. The cultivated area under Habarians as worked out from the various courses of river Indus prevalent during the period may have been 16 lacs and population 25 lacs.

Soomras, Sammas and Kalhoras, the master canal builders.

Under Soomras who ruled from 1011 to 1351, the river Indus seems to have changed its course at least three times causing destruction of irrigation system and change of their capital but they seem to have quickly reestablished the canal system as dynasty did not change for 340 years. Soomras were replaced by Sammas who ruled from 1351 to 1525 AD. Some of the canals built by them survived for more than three hundred years up to the British times. I have been able to find sixteen canals of early British period going back to Samma times. The area under cultivation under Sammas may have reached 16 to 17 lacs and the population to 25 lacs. Overthrow of Sammas and their replacement by Arghoons and Turkhans, gave rise to a civil war between new rulers and the rural cultivator community. Even the Mughal Governor was not able to rectify the situation, thus population reduced to 15 lacs in 175 years when Kalhoras rose in 1700 AD.

Sindh's population reduced to 45% by change of course of river and abandoning of millions of acres of irrigated land.

Kalhoras were master canal builders matched in history only by the British. They improved irrigation system and increased the area under cultivation from 9 to 10 lacs in 1700 AD to about 21 lacs in 1758. The population too rose from about 15 lacs to 30 lacs, but this glory was also short-lived. The river changed its course in 1758 deserting its old bed near Hala and adopted the present course. The old course passed from Hala, Oderola, Nasarpur, Shaikh Bhirkio, Tando Mohammad Khan, Matli, Talhar and Badin to Kori creek. This situation created anti-government uprising under local Baluchi Chiefs, who after 25 years, overthrew Kalhoras and established their own dynasty. From 1772 to 1783 AD there was civil war for power between Kalhoras and Baluchi tribes, who having won put the Talpurs at the helm of affairs.

British make improvements to reduce labor on canal maintenance.

Talpurs were not able to repair the loss caused by change of course of the river Indus. The irrigation system was mismanaged and the rural population busy in clearance of canals and cultivation was more than 1.6 persons per acre of land.

When British took over in 1843, they

(i) Applied engineering skill in designing of canals, reducing the amount of annual silt clearance and thereby reducing the ratio of rural population per each area of land irrigated, which as a consequence increased to 30 lac acres by 1930.

(ii) They reduced the length of canals per unit of land brought under canal command.

(iii) Periodical flooding of cultivated lands was eliminated by the construction of flood protective embankments and also thereby eliminating the labor spent in re-leveling and reclaiming such lands.

(iv) Animal husbandry (an alternative occupation) reduced due to reduction of pasture lands, which came under plough and making rural labor surplus; thus paving a way for the migration to urban areas resulting into industrial establishments and industrial labor. By 1921 the ratio of acreage cultivated to population had reduced to 1.18 as compared to 1.64 only 80 years before.

Pre-British canals and their peculiarities.

In order to understand the irrigation system as was being practiced before the advent of modern engineering methods of survey and design, the study of pre-British period canal system is necessary. Fortunately for us there is complete record of pre-British canals, their lengths, area under their command, the slope and direction of annals, silting and desilting problems and special problems created by use of bare eye and human judgment instead of using a dumpy level, leveling rod and chain. Hughes Gazetteer of 1876 gives list of the canals, running over two pages. From his list only length of canals and their source of supply has been studied. Following are a few conclusions which apply to all canals operating from the days of early irrigation:

(i) Canals lay obliquely to the direction of flow of the Indus in most of Sindh, exception being the area north west of Sukkur and west of Kashmore. This was done to get better slope for the channels, so as to reduce silting problems.

(ii) No canal had its mouth where river had a permanent (Sukkur and Hyderabad) back.

(iii) The canals were not deep enough to draw water from the river in winter.

(iv) The canals some times had sharp bends causing erosion or silt deposits.

(v) Old beds or abandoned branches of the river were often converted into a canal or part of it. Such branches often had poor slopes, awkward bends and needed annual desilting.

(vi) The mouths of canals often silted up during the season and needed cleaning.

(vii) Most of the canals supplied water by gravity during most of the inundation season, but occasionally water had to be lifted by means of Persian wheels to irrigate adjoining lands. There were canals or major portion of them, which were flowing in the cutting and water, had to be lifted from them to adjoining lands at all times.

(viii) Some important canals like Sindh Wah and Begari, instead of having mouth from the Indus, took off from Sindh Dhoro. Some of them were given more than one mouth.

(ix) Choking up of the mouth of canal by silting or fall into the level of river created precarious conditions for the farmers. A late rise of the river led to late planting or its early fall resulted in lack of final dozes of irrigation. In both cases, the crops were poor. Lifting of land in it self was time-consuming. Persian wheels supplying ¼ cusec of water at the best, and operating a maximum of 8 hours a day could not command more than 8 acres during the inundation season. The farmer was not able to recover the labor charges, assuming that animals were fed on pasture land without use of special feed grown for them.

(x) When river had no flood protective embankments, floods were more frequent and the chances of destruction of crops increased.

(xi) No regulators were provided at the heads of canals.

(xii) No consideration was given to the slope and cross-section of the canal to maintain a velocity of water, so that neither silting nor erosion may take place.

(xiii) Had the canals been long enough, and had it been planned that they will be sufficiently deep and have free run for some miles, before they supply water by gravity, water could have been made available to the farmers early as well as late in the season, to ensure availability of irrigation water in the whole of inundation season.

(xiv) Due to these uncertainties, pessimism and fatalism had prevailed in Sindh's farming community, over the centuries.

(xv) Since crop could fail any year, the farmers adopted animal husbandry as a source of additional income, as the river water flooded vast areas of land outside cultivated area and luxuriant grasses grew on them, farmers raised cattle on these pastures, providing them with an assured source of income in the lean years.

(xvi) Since flooding of land and destruction in normal years must have taken almost same proportion every year for Sindh as a whole, loss of crops in terms of percentage under irrigation must have remained almost the same, and production most probably changed very little, except when major hydrological changes in the course of the river Indus took place.

Due to these peculiar circumstances there were hardly any famines in Sindh. The only reported famines in Sindh since 1709 AD were in the Upper Sindh in 1820 and 1822 AD and most probably were due to famous Kashmore floods destroying Jacobabad, Shikarpur, Larkana and northern Dadu districts. Similar floods took place in 1942 and 1948. (Bhatia: Famines in India – 1860-1865 AD, London, 1967). Sindh must, however, have faced famines for some years continuously since 1758 AD when the river Indus changed its course near Hala, abandoning its old bed passing near Nasarpur, Shaikh Bhirkio, Tando Ghulam Ali, Old Badin, Kadhan and Rahimki Bazar, to the present course west of Hyderabad. As a result at least 1 million acres of land must have gone out of cultivation, which were later reclaimed and re-irrigated after opening of Kotri barrage.

(xvii) Some lands lying above the level of water in the canals, though within the command area and fertile, were left uncultivated.

(xviii) Only Kharif crop could be grown on these canals.

(xix) Many times canals did not have their mouths in the river itself but rather in lakes, and depressions like Sindh Dhoro, and were filled up naturally or artificially in the inundation season. This helped in silt depositing in the depression and canals did not have serious silting problems. On the other hand, level of water in the lakes was always lower than the river and therefore canals did not attain the levels they otherwise could have, reducing the area under command, and also the number of days water could be supplied.

Fatalist attitude of Sindhis due to Indus.

This brief history simply shows the unreliability of irrigation system over past 5000 years. There was one thing more; the canals took off from the river Indus for the purpose of irrigation. The level of water in the canals fluctuated with the level of water in the river.

This was beyond any body's control. Canals usually were flowering from mid-June onwards and stopped flowing by mid-October, when level in the river fell below the level of surrounding lands. Some areas were lucky to have water for 120 days although most of the areas in Sindh were getting water only for 90 days. Lower Sindh except that on Fuleli Canal was still unfortunate where the water was available for 75 days. The only crop that could be grown in the short period was rice. Varieties of it and yields per acre depended upon the number of days water would be available. Even during this short period, there will be years when water would come in the canal either too late or recede too early. There would be even fluctuation in canals during the mid of inundation season. Out of every 3 years crop would fail during one year, or it would be much below average. Thus the farmers became fatalist, leaving every thing to the luck and chance, as the river was too mighty and beyond their control. The earlier dynasties neither had the means nor the know-how and organization to over-come the fluctuations in the level of water in the canals.

Sukkur Barrage takes shape.

It was the British who came, at least as far Sindh is concerned, as a 'Blessing from Blue' and their attention to the irrigation system drawn in their early days. As far back as 1859, Fife, Superintendent Engineer in Sindh, recommended a weir (barrage) across the river Indus almost at the present position of the Sukkur Barrage. Weir was to control the level of water in the river Indus and a canal was to take off from this point to irrigate present Khairpur, Nawabshah and Hyderabad districts. The scheme went under changes at various stages adding more canals and finally came the Sukkur Barrage. In 1859 the technology of the engineering design was not highly advanced and machines were not available for construction purposes. Diesel and petrol engines were not yet invented and it was the age of steam engine with heavy boilers and yet it was a courageous proposal. Sukkur Barrage met the obstacles of labor (32,000 laborers for 10 years and 77,000 laborers for 5 months a year and over 10 years) by use of machines. The Suez Canal built in 1869 was a s wide as Nara Canal and only 22 miles long and even for this new machines had to be designed and built. A weir on the Indus in 1859 would have brought up technical problems beyond imagination at that stage of technological development. It had to wait another 57 years for the Government approval to start the surveys.

Purpose of the Barrage.

Sukkur Barrage is meant to maintain the desired level of water on the upstream side of river Indus called as pond. When water in the river is in excess, the surplus has to be allowed to flow downstream by raising the gates and when there is shortfall; flow of water to the downstream side is either reduced or cut off to maintain desired level on the upstream side. The designed level of water as envisaged in the plan was 194.5 feet above sea level. Since the bottom of the river at barrage gates is maintained at 177 feet above sea level, so 66 gates 50 feet wide and 20 feet high were built to maintain the level. The gates were separated by piers 10 ft. wide. Since construction of Sukkur Barrage, a large number of barrages have come up on the Indus and its tributaries in East Punjab and Pakistan. This has reduced the quantity of water flowing downstream and Sukkur Barrage is meant to hold this water and supply the canals taking off from it. 72% of total area on these canals is perennial i.e., they get water year around instead of 50-120 days before its start in 1932. The total area under the command of the barrage is 82 lac acres of which 76.3 lacs is cultivable and of this more than 90 percent is cultivated annually. Before the Barrage, total area under cultivation in Sindh was 30 lac acres and that in Sukkur Barrage command accounted for 18.30 lac acres. The four-fold increase in the area under cultivation plus assured water supply year around changed the attitude of the community toward luck and fatalism in Sindh.

Muslim Education-the first and immediate outcome of Barrage.

It should not surprise many, if it is disclosed that Sukkur Barrage was responsible for bringing large scale awakening in Sindh as consequence of economic benefits. A large number of students from the rural areas turned up in the cities for education, immediately after opening of Sukkur Barrage. Such was the miracle caused by this gigantic work executed between 1922 to 1932. It led to the separation of Sindh from Bombay Presidency in 1935. If Sindh had not been separated at this stage, Pakistan would not have been created.

Standard of operation.

The standard of operation of the canal system has been highly efficient. Breaches in canals, though too rare, still occur occasionally but are repaired in extremely short time without much loss to the crops. Sindh celebrated 50th anniversary of this barrage recently and as a token of gratefulness, invited engineer Sir Musto's two daughters and rewarded them on this occasion. Musto was responsible for designing and execution of head-works. He was invited after his retirement in 1948 to look into to the problem of some cracks in this very barrage. It is true that Sukkur barrage cannot last for ever but the proper maintenance can carry it through many decades to come.

Collapsing of Gate pm 19-12-1982.

It was unfortunate that one gate of the barrage, out of original 66, is collapsed. I was not able to verify this figure. The original report of Bombay Presidency puts 66 gates and now only 64 gates are reported. None is missing and the mistake is 'made only in reporting'. When the collapse of one gate was reported a shock wave hit the populance of Sindh specially the rural area depending upon agriculture. The public was more frightened by a hysterical press. An uncalled for criticism of the Department of Irrigation was on the lips of every one who heard of it. There would have been a row in Sindh Council, had the Governor of Sindh not issued a timely statement. Fortunately, the situation was fully controllable from engineering point of view, as is mentioned below. But what would have happened if the barrage were to give away. We have the answer to this question in the history of Sindh. A change of course of the river Indus in 1758 destroyed irrigation system in a part of Sindh below present Hala, by having abandoned one million acres of land. It caused turmoil, migration of population, disease, misery and death. The population of Sindh reduced from 30 lacs to 14 lacs. The government was toppled and three princes of Kalhora dynasty were replaced one after the other. Ghulam Shah Kalhoro tried his utmost and so too Sarfraz Kalhoro, yet people were in revolt. The government was finally replaced by Talpur dynasty in 1783, but by that time the damage had already been done, population had reduced and that which survived had to be readjusted along the river banks and new canals. It did not rise beyond 14 lacs proving high death rate.

What would happen if Sukkur Barrage gave away.

The 82 lac acres under command of Sukkur Barrage are responsible for employment of 80 lac people of rural Sindh. The cultivated land produces enough to feed not only the rural areas and urban towns in Sindh but also makes adequate surplus to be exported. The cotton produce in this area is responsible for running textile industry in Sindh leaving some surplus also for export. Probably 120 lac people thus depend upon it. What would happen if the Sukkur Barrage gives away, nobody can imagine. It would almost be equivalent to resurrection for Pakistan. With most of Sindh turned into desert any government would collapse overnight, even the existence of country may become doubtful. No foreign aid or assistance could support this population for 10 years until a new barrage could be constructed but luckily this was not the case.

What would have happened if gate would have given away earlier.

It was not the Barrage that had given away; it was one of the gates, which now has been replaced. But what would have happened, if the gate had given away earlier than December 19th. The canals of Sukkur Barrage close for annual repair normally from 25th December to 10th January, though for a few years in the past they are closed from January 6 to 21st. Since the gates hold water on upstream side of the barrage such a happening 3 months earlier would have possibly meant no winter crops. It was the cool mind of Mr. Dahar, the Secretary Irrigation that helped to take correct decisions in series hour by hoar and day by day to rectify trouble, when the public slept. If trouble had occurred earlier probably the public would have agitated to destroy his coolness and correct decisions. During this period canal gates are lifted and water flows downstream of the barrage in the river Indus. It is not wasted but is collected at Kotri Barrage command area. When the gate No.31 gave away, it could no longer hold the water. The gate could have been left in position for another 17 days for the closure period to start. But it would have been extremely unwise as damage may have increased to jam the door, so it was pulled up; definitely a very wise decision. It was also pulled up to find out the causes of damage to the gates. In my opinion there would be no damage to the standing crops or loss in cultivated area, because evapo-transpiration from fields would only be one inch of water, as compared to six inches in each 15 days from April to August. Water requirement of the crops thus was nominal.

Difficulties in replacement of gate.

Then arose another serious problem of replacement of damaged gate by another weighing 40/50 tons. The irrigation department after construction of barrage had neither means nor machinery to execute this task in running water. They required barges equipped with cranes. They also need crew to under-take the work. Their mechanical staff trained for this job was limited to few persons, they had no other alternative but to seek help from outside and no other agency of the government of Sindh had such facilities. The facilities were available with Karachi Ship yard and Engineering Works and Pakistan Navy. They were very kind to come to rescue, and for which people owe them thanks. Sindh also must express its gratefulness to Mr. H.M. Dahar, who showed all qualities of an able engineer and leader during these gloomy days.

It is worthwhile recalling here that for construction of barrage, they had used floating dredgers, 25 ton and 10 ton floating electric cranes, floating pipe lines, barge pontoons, floating pile drivers and all sort of equipment for working on and under water. No such equipment was needed for maintenance and the irrigation department does not have a single piece of floating equipment today to carry out even the painting of gates. This handicap paralyzed the whole department, when the gate collapsed.

Corrosion and its mechanism.

Corrosion in air:

Corrosion is destruction of metal by electro-chemical or simple chemical action. Steel is stronger than iron as it has some amount of carbon. Wrought iron has no carbon. Wrought iron due to reaction with atmospheric oxygen, oxidizes forming rust, but in steels carbon turns into carbonate and iron into oxide. Thus the corrosion in Steels is much quicker. Since carbon is present uniformly throughout the section of steel, corrosion attacks the inter-crystalline boundaries and pit formation is the result. Corrosion needs moisture and oxygen both of which are present in atmosphere.

Corrosion in presence of water.

If the metal is not in touch with water, initial corrosion or rust formation forms a protective layer and further corrosion is retarded though not stopped altogether. In water rate of corrosion in high but in running water this is further accelerated due to increased contact of dissolved oxygen. At high temperatures rate of corrosion increases i.e., it would be faster in hot summers of Sindh than in winters. Continuous splashing of water on steel allows both atmosphere and dissolved oxygen to further accelerate corrosion. The rust so formed has a tendency to dissolve. The barrage waters at Gudu, Sukkur and Kotri contain hydrogen sulphide, formed due to decay of vegetative material in suspension of stagnant or slow flowing waters specially in winters. Hydrogen sulphide hastens corrosion by formation of iron sulphates and sulphides soluble in water. If water was stagnant a balance would be achieved and no more sulphides or sulphate corrosion would occur but in moving water attack is continuous as iron sulphates and sulphides get washed off. Then there are anaerobic bacteria, which break sulphates in water and soil and help to increase corrosion.

Corrosion between two different metals.

If two metals of different chemical compositions are in contact in presence of water or soil, there is established electro-potential or electric current between them and corrosion starts. This is why corrosion is caused at the joint by welding two pieces of steel, as the welding material does not have the same chemical composition as that of the metals joined together. In gas lines to overcome this, electric current is passed through the pipe lines in opposite direction, now known as cathode treatment. This is one reason why in case of bridge and other structures under stress, riveting is resorted to in place of welding to avoid corrosion due to electro-chemical action.

Corrosion fatigue.

Stresses in the metal i.e., doors of Sukkur Barrage caused by static water pressure, dynamic (i.e., flowing water) pressure and natural vibrations produced at high discharges of water cause stresses. Added to this are vibrations caused by heavy traffic across the bridge. The repeated stresses cause failure of metal at much below their ultimate tensile strength, before gates were fabricated. If metal is corroded, failure is still at much lower tensile strength. This was the main cause of failure of the gate.

Corrosion is retarded if the metal is cleaned (by sand blasting in case of barrage gates) and repainted every year but when sand blasting is done, corrosion (rust) and some layer of steel, however thin, is also removed. Thus sections keep reducing in thickness and they are not able to stand the pressure of water and other stress. The combined action of repeated stresses and corrosion cause what is technically termed as corrosion fatigue. There is no fixed corrosion fatigue limit for any metal under the condition of exposure, namely moisture, running water, splashing water, atmospheric oxygen, dissolved oxygen, hydrogen sulphide and bacteria directly responsible for corrosion and stresses caused by head of water and vibration caused by water and lately by traffic, as has happened at the Sukkur Barrage gates.

Prevention of Corrosion.

Prevention of corrosion by painting in itself is a highly specialized field. The metallic components of gates have to be cleaned by sand blasting; use of any manual method would not remove all the corrosion or rust and it would simply be waste and as any cost of paint will go off from corroded section, the corroded spots will expand to adjoining areas underneath the paint, remove it and the process will go on.

After sand blasting the surface is coated with chromic acid (M2Cr2O7). This would ensure removal of any residual corrosion and also form an underneath protective coat. Paints for underneath water services have been greatly improved in recent years, by use of phenolic-chlorinated rubber and other synthetic resin bases. Tung oil has replaced linseed oil commonly used hitherto. In addition, there are inhibitive pigments. Epoxies resins have also been used with some degree of success. This subject of paints is undergoing revolutionary changes so fast that this recommendation may not apply after a few years.

Apparatus used for detecting depth of corrosion.

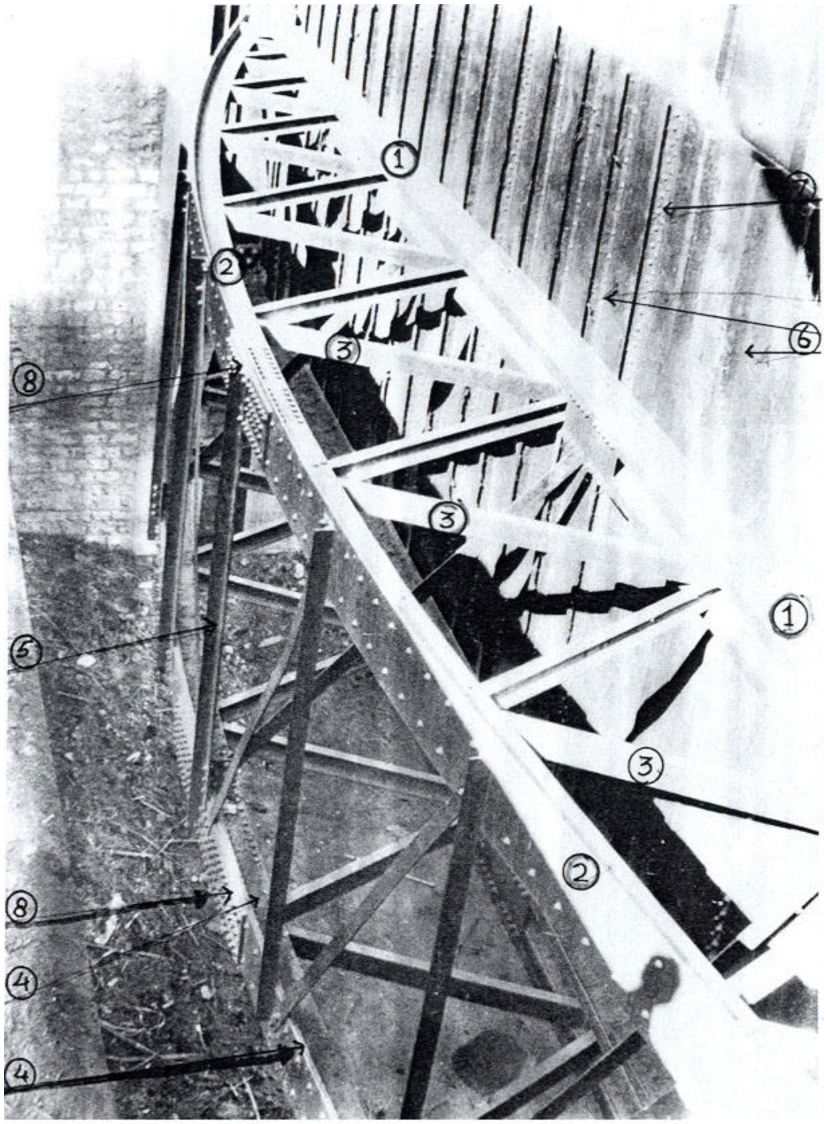
There are various detectors like ultrasonic equipment, magnetic crack detectors, nuclear flow detectors and X-Ray detectors which can show the depth of corrosion damage, but the extent to which the tensile strength has been reduced by corrosion, pressure load and vibration could only be found by taking out some of the components and putting them under universal testing machines for both tensile and compression strength.

Various components of gate and their working.

Explanation of figures.

Figure 'A' shows gate No.9 lying on an island artificially created for the river training. No.1 shows a string, No.2 the bow and No.3 the braces of the upper bow string girder. There are 2 such girders, one at the top and the other at the bottom. The bottom girdier is shown as No.4. The two girders, the upper and the lower are connected by braces No.5. No. 6 shows the reinforced flat plates. The girder is at the back of plate and on the downstream side of the flat plates. The girder is at the back of plate and on the downstream side of the plates. The plates are riveted to the bow of the girder and they are also riveted to each other as shown at 7. The gate originally was fabricated in 3 parts which were joined by bolting them. No.8 shows such joints. Water is held on the front of the plates which are 50 ft. wide and 20 ft. high. The total pressure of water on the plates or each gate when submerged 18 ft. deep would approximately be 300 tons. This pressure is borne by the bow-string girders. The horizontal braces are meant to strengthen the bow and string girder and the vertical braces equalize the load between upper and the lower girders, as there is more pressure on the lower girder than the upper one due to depth of water. The horizontal braces are formed from steel channels, and the vertical braces are made from angle iron.

Iron and steel corrode due to action of oxygen of the atmosphere. Corrosion is increased if iron is submerged into water as dissolved oxygen in presence of water would react faster than if it were outside. If there is hydrogen sulphite present in the water corrosion is much faster. In case of gates the front plates remain partially submerged into water for some months and fully for the rest of the year. Water escaping underneath splashes over the lower bow-string girder, and also the vertical braces. The action of corrosion is much faster in case of water splashing on metal, than when fully submerged, as more and more oxygen would come in contact with metal both from water and atmosphere with every splash. This cannot be stopped or eliminated altogether. As a means of maintenance the gates are cleaned each year by sand blasting and painting. Every time the gate is sand blasted some of the metal is removed along with corroded material. The annual cleaning, therefore, results in thinning down of gates specially the lower braces and there is no escape from it. This would in general reduce the life of the gates and there would be a time limit when the gates would need replacement. It is not being suggested that the gates may be replaced immediately, but it is only to point out that there will be a time limit to the life of gates. If one of the gates gave away it is an indication that some of its components, and to be more specific, the lower horizontal braces, had worn out to their yielding point.



Gate No. 9
Fig. 'A' shows upper bow-string girder. The lower bow is visible and vertical braces connecting the two girders are also seen. They are in good shape.

Figure 'B' shows gate No. 10 from the front. The plates as riveted to the bow-string girder and joints are clearly visible.

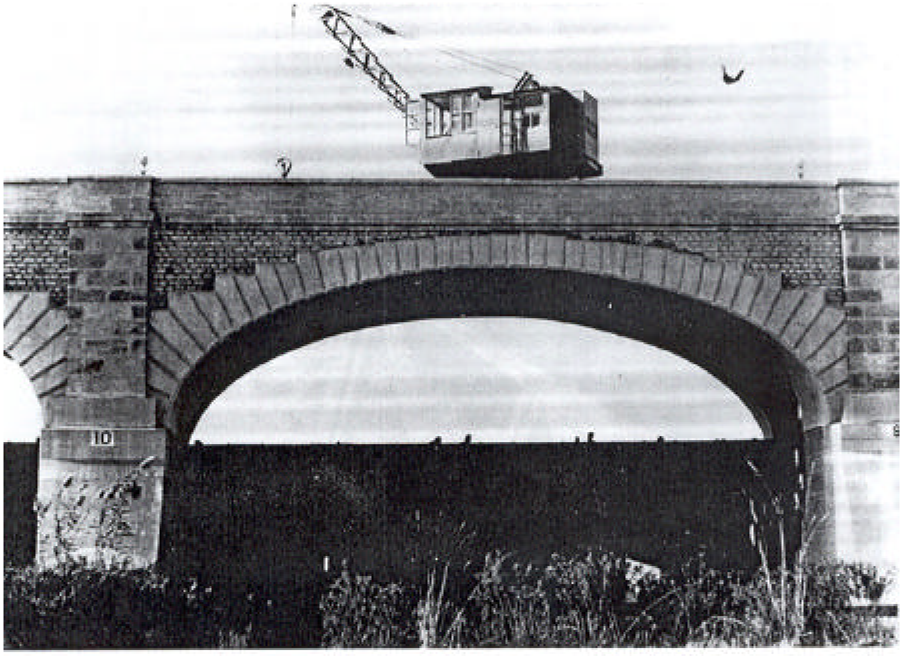


Fig. B. Gate No. 10 from front.

Figure 'C' shows the cause and type of failures that occur. In this No. 1 shows shear failure of a vertical brace and No. 2 shows heavy corrosion of a vertical brace and No. 3

shows heavy corrosion of the bottom bow of bow-string girder.
Figure 'D' shows the gate's position, with water flowing underneath it. Water seen in the figure is on the downstream side. The figure shows lower bow as No. 1 string and No. 2 and 3 are horizontal lower braces. No. 4 are vertical braces and No. 5 are plates. There is more corrosion in the lower parts than upper parts. This picture pertains to gate adjoining No. 31. The two gates are in the centre of stream and splashing action against them is maximum.

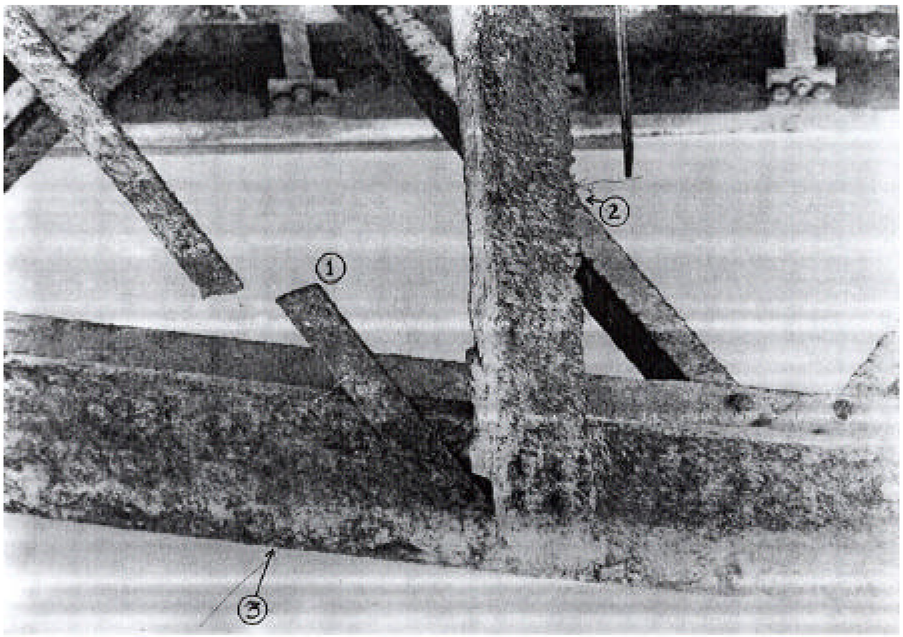


Fig. C (1) Shear failure of vertical brace.
(2) Heavy corrosion of vertical brace.
(3) Heavy corrosion of bottom bow of bow-string girder.

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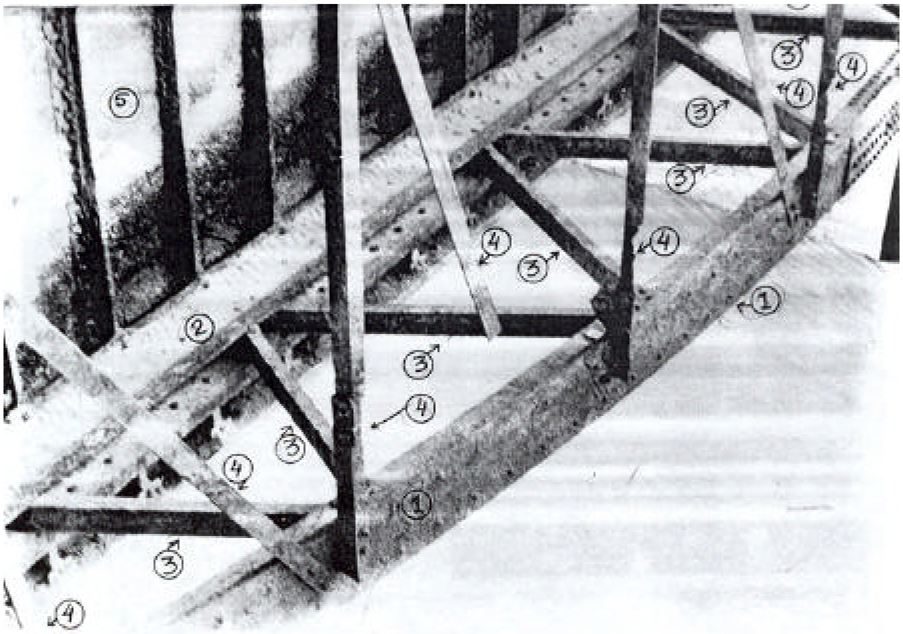

Fig. D. Gate in raised position with water flowing underneath it. Water shown in the figure is on downstream side. When gate is closed fully or partially, there is pressure of water on face of gate. This is taken by plates (5) fitted on pair of specially fabricated bow-string girder. No. (2) shows the string, number (1) the bow. Horizontal braces (3) connect the bow to string and whole assembly works as girder. There are two girders, upper (not shown in picture) and lower. They are connected by vertical braces number (4).

The lower bow-string girder is exposed to water and gets corroded. Further there are stresses caused by vibrations which too are absorbed by the components causing metallic fatigue. Corrosion combined with fatigue caused failure of braces marked as (3).

Figure 'E' shows gate No. 10 partially disassembled to be taken for reassembly in place of gate No. 31. The various components were numbered for ease of reassembly.

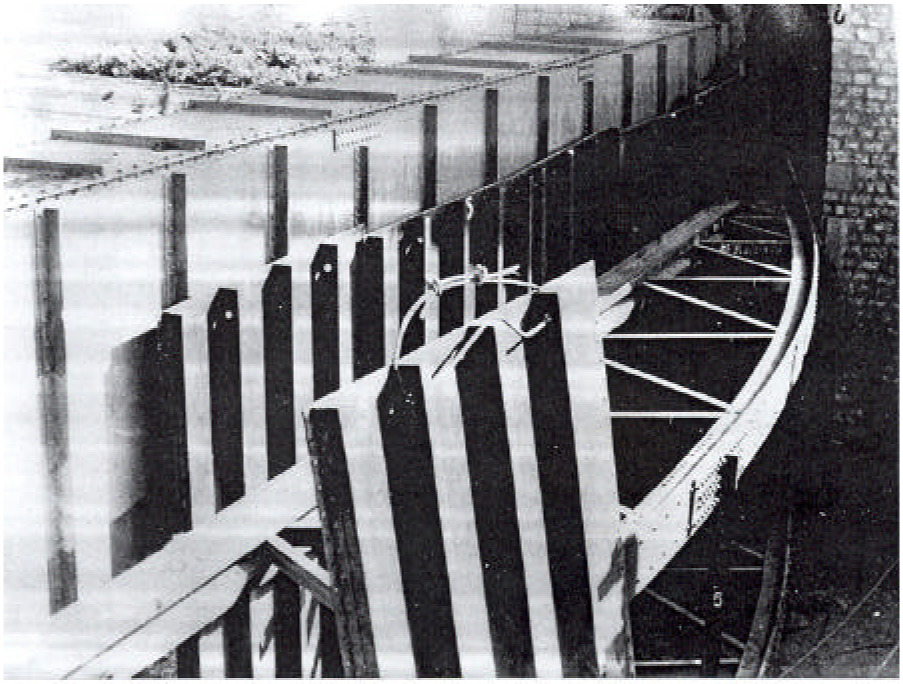

Fig. E. Gate No. 10, partially dismantled to be taken and reassembled in place of gate No. 31. Components are numbered for systematic reassembly.
Gate No. 10 is in disuse for years. For the purpose of river training an artificial island was created.It is now lying on dry land.

Figure 'F' shows gate No. 31 which failed, now raised and its front plate removed. The workers having seen the photographer left their work and posed. The picture shows the exact nature of failure. The front plates have been disassembled and removed. The upper bow-string girder apparently has not bent and yielded. In case of the lower girder the horizontal braces of bow-string girder have bent, twisted and eventually crumbled under pressure of water. They appear in this picture at the feet of workers and are badly distorted. The front string has bent and almost joined the bow of girder. This makes it clear that the failure occurred on account of the weakening of braces, but it is only a guess. Full analysis could be had only on examination of each component of this gate by specialists. The two figure 'E' and 'F' also show that most probably the most stressed girders are in the centre of the barrage.

Fig. F. The lower and upper bow-string girders each having its own horizontal braces and vertical braces connecting the two. Note that the horizontal braces of upper bow-string are in of the lower one have folded and warped, and bow and string girders of lower one are almost touching each other, save for the crushed braces between them.

G. Artificial island.

Conclusion, suggestions and recommendation.

It is suggested that a Commission may be set up for examination of the gates of Sukkur Barrage.

Once this Commission is set up it would be advisable to examine the gates of the other two barrages in Sindh. Similar Commissions can be set up by the Government of Punjab for their own barrages. A Commission for the whole Pakistan will not be feasible as it would dilute the very important issue of Sukkur Barrage.

Another Commissions to be set up specially to examine the structures of the Sukkur Barrage itself. It must include specialists from world over, experienced in such works. This is essential in view of the fact that cracks started developing in Sukkur Barrage in 1948 and though they are being repaired but new hair cracks are being located periodically.

Some of the regulators of the canals of Sukkur Barrage have given away. The engineers were able to control the physical damage to the crops, but all of such structures may be examined either by the same Commission or a team of specialists.

Heavy traffic over the Sukkur Barrage should be banned immediately. Traffic creates vibrations which are transmitted right up to the foundation. The alternating stresses created by vibration will result into premature failure of the structures. This could be avoided by banning heavy traffic over the barrage. Even for light vehicles speed limit may be fixed and enforced.

Traffic should be banned in case of Kotri Barrage too. Once this is done tendency would be for the vehicles to use Gudu Barrage Bridge as crossing point for upper Sindh and Quetta and thus by averting one damage, we will open the way for another damage.

Since all the barrages of Sindh need to be banned for heavy vehicular traffic, road bridges across the Indus at Hyderabad (for Super Highway), Khairpur and Ghotiki may be planned on top priority basis.

A highly powered and specialist maintenance cell may be created directly under the Secretary Irrigation, Government of Sindh to carry out maintenance of the barrage gates as well as canal gates. This work involving a lot of mechanical know-how may also need a specialist adviser to the Secretary.

Providing facilities like portable barged mounted crane for Sindh directly under Secretary Irrigation along with necessary tools for replacement of gates or their components.