PAPER No. 203.

SOME NOTES ON GUNITE AND ITS USES ON CERTAIN WORKS ON THE NORTH WESTERN RAILWAY.

(By S. L. Kumar, Assistant Bridge Engineer.)

Gunite is a mixture of cement and sand deposited in the form of a cement plaster ejected under a pressure of 30 to 40 lb. per square inch from a "Cement Gun." The process of placing gunite is called guniting. It must not be confused with pressure grouting in which a mixture of sand and cement is forced in the form of grout into masonry to fill up voids inside the mass. In guniting the sand and cement are mixed almost dry, the water being added as the mixture issues from the gun, whereas in pressure grouting the water, sand and cement are mixed to form a liquid cement paste or grout which is forced under pressure into the mass of masonry being treated.

The cement gun is a patented product made by the "Cement Gun Company Limited, London." Messrs. John Fleming & Co., Limited, Engineers and Contractors, Bombay, represent the Cement Gun Company of Great Britain in India and Ceylon. They have executed a number of gunite contracts in this country.

The use of guniting is not new on the North Western Railway and in addition to the description of two recent works carried out under the author's supervision, a note has been included on the lining of the Khojak Tunnel, which was gunited in 1928-30.

The M. E. S. at Karachi used guniting for repairing reinforced concrete pillars and floors at Manora Island near Karachi. They had been so badly corroded that the steel reinforcement had been exposed. By this method it was possible to effect repairs economically and save thereby the cost of reconstruction, which was the only other alternative. The M. E. S. also utilized this process for reconditioning the masonry retaining walls of Manora fort and barracks.

The chief uses of guniting to a Civil Engineer are :—

1. Repairing weathered concrete or masonry.

2. Providing a water-proof lining on water reservoirs, irrigation channels, sewers, dams, spill ways, docks and jetties, etc.

3. Relining steel coal bunkers.

4. Relining chimneys, both steel and masonry.

5. Encasing steelwork which is already corroded or new steelwork to prevent corrosion, particularly under difficult conditions such as are obtained in structures submerged in sea water or exposed to strong sea breezes.

The equipment consists of:—

1. A cement gun complete with the placing nozzle, material hose and water pipe.

2. A compressor capable of delivering 200 to 250 c.ft. of free air per minute at a pressure of 80 to 100 lb. per square inch.

3. An air receiver of about 10 c.ft. capacity.

4. A water tank with 2 compartments with capacity varying according to the actual requirements.

The "Cement Gun" is manufactured by the Cement Gun Co., Ltd., London in the following three sizes. The size required for any particular work depends on the size of sand to be used and the area to be gunited.

Type of Cement Gun.	*Maximum grain diameter of sand.*
Type N-2	3/8"
„ N-1	1/4"
„ N-0	1/8 to 1/4 inch.

The largest size N-2 takes a 2" diameter hose and is used only for large areas. The medium size is used normally for all works with $1\frac{1}{2}$" diameter hose. The North Western Railway has only 2 cement guns of type N-0. These take 1" diameter hose.

The use of the cement gun is quite easy to understand. A mixture of almost dry sand and cement after it has been thoroughly hand mixed and screened, is charged into the "Feeding Chamber" (See Plate I) and the cone door closed. The mixture drops from the feeding chamber to the "Working Chamber." Compressed air at a pressure of 30 to 40 lb./□" pressure is led into the gun as well as to the air motor on the side of the gun. Geared to the air motor, which starts rotating at 30 to 40 revolutions per minute, is the "Feeding Wheel" which carries an agitator. This serves to keep the mixture thoroughly stirred. On the

" Feeding Wheel " there are small radial projections, which scoop the mixture round to the outlet valve to which is connected the " Material pipe." The compressed air is admitted into the working chamber just above this pipe, in such a way that it forces the mixture between the projections on the feeding wheel into the outlet valve down the material pipe to the placing nozzle at the end. The quantity of the mixture entering the material pipe can be regulated by controlling the speed of the air motor and also by regulating the pressure on a lever applied to the outlet valve.

The air pressure also holds the cone door at the top of the feeding chamber pressed against the wall of the chamber, air tightness being obtained by means of a rubber ring let into the groove on the sides. A continuous supply of the mixture is obtained by closing the cone door between the working chamber and the feeding chamber. The exhaust valve of the feeding chamber is then opened. As the pressure of air in the feeding chamber drops to the atmospheric pressure, the lower cone door stops the leakage of air from the working chamber to the feeding chamber. The upper cone door drops automatically and the feeding chamber can then be charged with the mixture without interrupting the shooting of the mixture from the " working chamber."

Compressed air is now let into the feeding chamber after closing the exhaust valve. As soon as the pressures in the feeding and the working chambers equalize the lower cone door between the two chambers automatically drops and the mixture slides down into the working chamber.

The Placing Nozzle is a rubber-lined brass nozzle fixed to the end of the " Material Pipe." Water is let into this nozzle from a connection on the side at a pressure of about 40 lb. per square inch. A water regulating valve controls the quantity of water delivered to the nozzle. The water after passing through the fine holes in the annular water chamber, mixes with the cement and sand mixture, while it is being shot out of the nozzle. The nozzle is kept at a distance of about three feet from the surface to be gunited.

The " Material hose " is an armoured rubber pipe lined with a special quality of hard rubber. It is available in lengths of about 50 feet.

When the mixture of cement and sand accompanied by a fine stream of water first reaches the surface to be gunited, a thin layer of pure cement is formed on it, the sand being lost by the rebound. As soon as this layer of cement is formed, the sand in the mixture following adheres to the cement. This process is repeated simultaneously, the excess of sand in all cases dropping after rebound. There is, however, no loss of cement unless too little water is used at the nozzle. If too much water is used, the mixture becomes too soft and runs down the surface. Faulty workmanship thus at once becomes apparent to the

supervisor. If the gunite sticks to the surface, it means that the work is going on correctly. A mixture of 3 parts of sand to 1 part of cement has been found by experience to be an ideal one. A richer mixture tends to produce hair cracks. An excess of sand in the mixture would be wasted in the rebound, though it can again be remixed with more cement and shot. If the mixture is correct, the gunite formed gives a uniform greasy lustre.

Gunite does not require any careful curing like ordinary concrete work as after twenty-four hours it becomes water-proof and is capable of absorbing but very little surface water. It is, however, desirable to continue watering for at least three days.

Rapid-hardening cement is used for guniting in England, but in India where the air temperature is usually higher, ordinary cement may be used except in places, where rapid setting of the gunite is absolutely necessary. Sand should be upto the usual specifications and must be washed and screened through a mesh suitable for the type of cement gun in use. A bone dry mixture of sand and cement should never be used as this prevents the correct inflow of water at the nozzle. If hand mixing of sand and cement is not considered satisfactory, a mixer may be employed.

Gunite should not be deposited in layers exceeding 2" in thickness. If a thickness in excess of 2 inches is required, another layer may be applied after the first layer has been allowed to set. The surface before applying the second layer should be thoroughly wetted and screeded lightly to remove the cement fat. Where better finish is desired, a "flash coat" of 1/16" thickness may be applied about four days after the last layer has been deposited.

Gunite is usually reinforced, particularly when applied to the surface of steel. The reinforcement provides a better bond and minimizes any tendency to surface cracking due to shrinkage. In case of masonry work where the raking out of the mortar joints will usually provide a prefect key to the gunite, reinforcement may be dispensed with. The reinforcement should have a mesh of 2 to 3 inches and a thickness of about 3/16 inches. It should be tack welded to the steel surface at suitable intervals in such a way as to be 1/4" to 1/2" clear of the surface. If this is not done, the sand rebounding from the surface during the process of guniting will lodge against the reinforcement and will form a hollow pocket, thus reducing the bond and also the strength of gunite.

On a plain surface such as that of a wall, gunite can be deposited at the rate of 100 to 120 square feet per hour when applied in a layer of about 1½" thickness. This does not include the time of moving scaffolding.

For repairing reinforced concrete structures by guniting the existing loose material must be carefully removed and the exposed reinforcement should be thoroughly cleaned. The reinforcement for guniting should be fixed all round the existing work either to the existing reinforcement or by means of wire nails secured into the existing concrete. The shuttering can then be fixed into position. It should be thoroughly wetted before the guniting is applied. As the wood dries it separates itself from the gunite. Shuttering can usually be struck within a few hours of the completion of guniting, the actual period depending upon the kind of cement used and the temperature of the air. Care should be taken during guniting to prevent rebound sand remaining in the forms and forming hollow pockets.

The following precautions must be observed while guniting :

1. A steel surface before guniting should be thoroughly cleaned so as to remove all rust, mill scale or paint. In case of masonry work, the mortar joints should be raked out to a depth of at least 3/4". The surface should be roughened and thoroughly wetted.

2. When starting guniting, blow pure compressed air on to the work to clean the material hose and to dislodge dust from the work. Then blow water under pressure.

3. The nozzle should always be kept at right angles to the surface to be gunited and at distance of about 30 to 35 inches.

4. In guniting corners the nozzle must be directed at their deepest points.

5. The nozzle operator and his mate must wear plain goggles to protect their eyes.

6. Trowelling or floating of the surface of the gunite is not permitted. The surface can be rendered smooth by the use of a light brush.

7. If the work is stopped for a short time, the nozzle should be placed with its jet downward so that any water escaping the regulating valve, should it leak, may not run into the material hose and clog it.

8. On ceasing work for a longer time, the gun, the material pipe and the nozzle must be thoroughly cleared of all mixture by blowing compressed air through them.

9. The gun must be thoroughly overhauled once a week.

10. The material pipe must not be kinked as this tends to clog it and also causes uneven wear of the rubber.

11. While removing clogs, the nozzle must be directed towards a place where no workman is standing as the sudden removal of a clog may result in the material being forced out with great violence.

12. Care should be taken during guniting to eliminate vibration of the structure.

The following are the advantages of gunitting over plastering by a trowel :—

(1) Gunite is dense and stronger than ordinary cement plaster and also water proof when of suitable thickness.

The average compressive strength of 1 : 4 gunite obtained by the German Government Materials Testing Bureau is 6528 lb. per square inch as compared to an average of 2360 lb. per square inch for well tamped ordinary 1 : 4 cement mortar. Thus gunite is about two and three quarter times as strong as the ordinary hand placed plaster.

M. E. S. Tests regarding compressive strength of gunite gave the following results :—

1 : 3 Gunite with unwashed sand, crushing strength after 7 days 3,700 lb. per square inch.

1 : 3 Gunite with washed sand, crushing strength after 7 days= 6000 lb. per square inch.

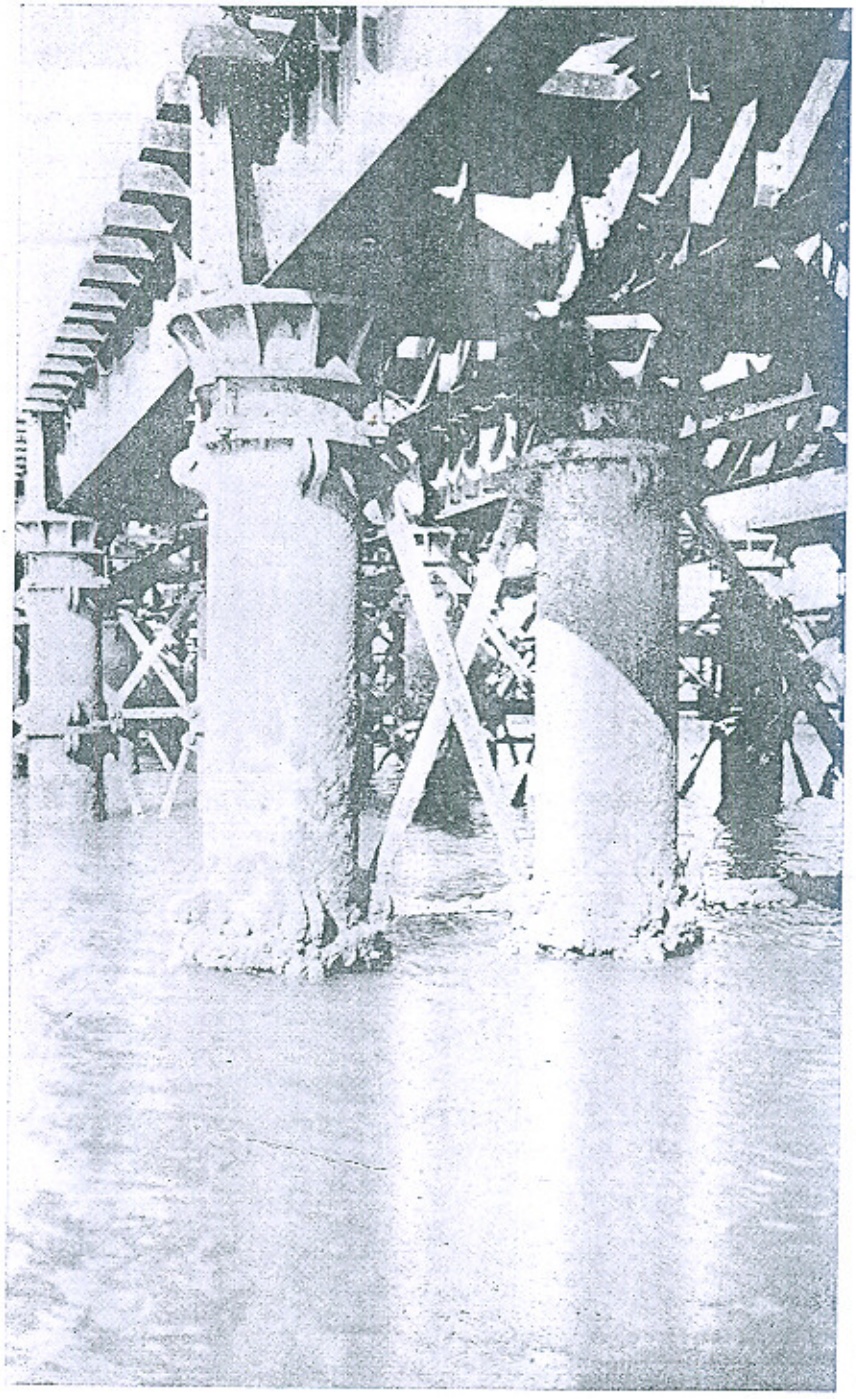
1 : 3 Gunite with specially graded and double washed sand= 10,000 lb. per square inch.

American tests as reported in the Engineering News Record of 4th July 1935, showed that 4" test cylinders " shot " as gunite was being placed, developed a strength of 7,000 lb. per square inch after 28 days.

(2) Gunite sets much more quickly than ordinary plastering.

(3) Owing to the deposition of the gunite under pressure the penetration of the mixture to every crevice is perfect. It is therefore, possible to guarantee adhesion to the old work.

(4) Gunite is comparatively free from shrinkage cracks. Experiments were tried at Manora by the M. E. S. to compare the effectiveness of repairs by Gunite and by the old method of trowelling. Those experiments indicated the advantage which guniting possessed over ordinary plastering. The repairs by ordinary plastering showed numerous hair cracks from which gunite was found to be immune. A similar experiment was tried by the author at bridge No. 275 on the Rohri Khanpur section described in detail further on.



THE ORIGINAL CORRODED BRACING
ON CHINNA CREEP BRIDGE.

The cost of guniting varies with the thickness of gunite required and also whether it is reinforced or not. The author understands that the Firm doing this class of work in India quotes ten annas per square foot for providing on a plane surface one inch thick gunite without reinforcement and one rupee eight annas per square foot for reinforced gunite about 1½" thick including a "flash coat" for obtaining a fine finish.

The following figures of cost were obtained on guniting done on the North Western Railway :—

(1) Unreinforced gunite from 1/3" to 1/2" thickness on the Khojak tunnel. — One anna per sq. foot.

(2) Unreinforced gunite from 1½" to 3½" thick gunite on piers of Bridge No. 275 on Rohri Khanpur Section. — Four annas per sq. foot.

(3) Reinforced gunite from 1½" to 2" thickness on China Creek Bridge at Karachi. — Re. 1-2-0 per sq. foot.

Further details of these works appear later in this paper. The figures given above do not include depreciation on the plant, which may be as much as about 2½ per cent. of the total cost of the work.

Guniting of new bracings of C. I. Pile bents of Chinna Creek Bridge at Karachi.

The Chinna Creek is a tidal creek between Karachi and Kiamari and is crossed by the North Western Railway by a girder bridge of 39 spans of about 32 feet each. The abutments of this bridge are of masonry or plain concrete, while the piers consist of twin cylindrical cast iron piles 2'—6" diameter 6 feet centre to centre and braced by one or two tiers of diagonal bracing of angles. The bridge carries three tracks and the pile bents under each track are secured to the bents under the other two by diagonal bracing. At the highest tide the water level is about five feet below the rail level or only about 9 inches below the underside of the cross girders and at the lowest tide the water falls to about 17·3 feet below the rail level.

To prevent corrosion on the girders of this bridge, exposed as it is to moist sea breezes, has all along been a problem. Many a well-advertised and well-known special paint had its reputation wrecked when tried at this bridge. The flange plates of the girders are painted once every six months and the web once a year. It was almost impossible to prevent corrosion on the diagonal bracings which were being alternately immersed and exposed twice every twenty-five hours. The bracing had become a mere skeleton of its original self and at places the

members had actually been cut in two parts by cumulative deterioration. It had thus become ineffective. It was decided to replace the top tier bracing by heavy plate girder bracings between the piles under each track and to cover them by gunite to prevent corrosion. The existing diagonal bracing in the lower tier and that between the bents under each track was not to be replaced.

Plate No. II shows the bracing as it originally existed and as it was proposed to be replaced. The bracing girders were riveted at the top to the cross girders and were secured to the existing cast iron lugs on the piles by gibs and cotters. Where there were no lugs on the piles the girders were fixed by straps round the piles.

It may be mentioned that on 23 bents, the length of the bracing girders below the cross girders varied between 7′—3″ and 8′—8″, on eight others the length was about 10′—9″, while the seven remaining ones were the deepest with lengths varying from 11′—6″ to 12′—6″. It was the lowest portion of these bracing girders that was difficult to gunite, being only a few inches above the level of the lowest spring tides.

The work was started on this bridge at the end of September 1935 and by the beginning of December the work of replacing the existing diagonal bracing with the new plate girder bracings was well advanced. Delays arose in starting guniting on account of the delay in the supply of some spares of the cement gun and of the expanded metal.

Although gunite is claimed to be perfectly water-proof, yet to make matters doubly sure it was decided to add Sika No. 4-A another water-proofer. This Sika is a highly corrosive alkaline liquid which when incorporated with the water used in making concrete makes it set more quickly and also renders it impervious to water. Preliminary tests showed that a proportion of one part by volume of Sika and 5 parts by volume of water when used for guniting rendered it impervious to sea water in 30 minutes. This was an essential condition as the time available for guniting the lower parts was very short. The work was programmed in accordance with the tide tables, the lowest parts being gunited during the period of the spring tides.

Guniting was started by the beginning of December. As guniting requires a skilled nozzle man and as none was available the results in the beginning were disappointing and the work had to be stopped. However, the work was restarted by the departmental labour and happily within a short time very good results were obtained. It would thus appear that with a working knowledge of the method of guniting and the equipment it is possible to train staff for this work within a short time. The work gunited in the beginning was later on improved by treating with a flash coat of gunite after screeding the surface of the first coat.

The gunite equipment consisted of—

1. 2 cement guns type N-0 complete with material hoses and nozzles.
2. 2 Air compressors.
3. One air receiver.
4. A water tank with two chambers for holding Sika mixed water. Water in one chamber at a pressure of 40 lb. per square inch was being used for guniting while Sika was being mixed with water in the other chamber.

The estimate provided for reinforced gunite one and a half inches thick all over the bracing girders and straps which secured them to the piles. The reinforcement consisted of expanded metal No. 10. This was tack welded to the girders all round as shown in Plate III. The expanded metal was necessary to provide sufficient adhesion between the gunite and the steel surface. For the welding work a 60-volt D. C. generator driven by an oil engine and having a capacity upto 200 amperes was utilized.

The cement guns and the water tanks were carried on timber rafts and were towed from one bent to another as required. The welding plant and the air compressors were at first kept on the abutments and later the former was mounted on a trolly running on one of the tracks which had been closed.

The mixture used in guniting was one part by volume of ordinary cement and three parts by volume of sand from Bholari or Lyari. The sand before use was screened through a sieve having 8 meshes to an inch and then washed thoroughly. For successful guniting it is essential that the mixture of cement and sand before it is charged into the gun, should be damp. It must not be bone-dry and it must not be sloppy. If the mixture is bone-dry, the cement issues from the nozzle like dust and is blown away. If the sand is too wet, the mixture clogs in the material pipe. A handful of the mixture with suitable proportion of water should be just sufficiently damp to hold together when squeezed. Experience showed that a moisture content of 1 per cent. by weight of sand was quite suitable.

In guniting, about 10 to 20 per cent. of the sand is lost in rebound from the surface which is being gunited. So the resultant mixture is 1 part cement to about $2\frac{1}{2}$ to $2\frac{3}{4}$ parts of sand.

Guniting of the web of the bracing girders was fairly easy but guniting of the flange plates on the sides was difficult as the piles on each side would not allow the nozzle to be kept at right angles to the surface to be gunited. Wooden strips were kept against the edge of the flange

plate to prevent excessive waste of materials, when shooting in such positions. Such wooden strips were also necessary for guniting the bottom portion of the girders and the straps round the piles. As Sika has a corrosive action on all organic matter, the hands of the operator were protected by leather gloves. The surface of the gunite was finished by rubbing it with a moonj brush.

Luckily, the lower of the two daily low tides occurred in the day time within about 5 hours in the morning to 20 hours in the evening. Guniting was only done during this tide. Artificial lighting was, however, found necessary and arranged for.

The labour required for guniting was as follows :

One Nozzle man.

One cooly to help nozzle man.

One cooly to hold wooden strips.

One mason to finish surface with a brush.

One gun operator.

Two khallasis to mix sand and cement.

Two coolies to charge the gun with the mixture.

Two khallasis with one cooly to mix Sika with water and regulate supply of water.

After a number of bents had been successfully gunited with a mixture of ordinary Portland Cement, sand and Sika mixed water, it became evident that the supply of Sika which had been arranged for, was inadequate for completing the work. Each gallon of Sika cost fifteen rupees and already 357 gallons had been arranged for. Further supply of Sika was not available as heavy stocks are not kept in this country. It was, therefore, decided to do guniting by using rapid hardening cement without Sika. This was done on all the remaining bracings upto seven and a half feet below the underside of the cross girders. Only the lowest portion of the deeper bracing girders was gunited with Sika and the ordinary cement. The difficulty in estimating the quantity of Sika required for the whole work had arisen, because the quantity of water required in shooting one bag of cement was not known. A record was, therefore, carefully maintained showing the amount of cement shot and amount of water and Sika used in gallons. It showed that on the average for one bag of cement (in the ratio of 1 volume cement to 3 volumes sand) 3 gallons of water and 0·6 gallons of Sika or approximately 2·9 gallons of liquid per c.ft. of cement. The low water-cement ratio in guniting is responsible for the increased strength of gunite.

In the original estimate 10,550 square feet of 1½" thick guniting had been provided for at the rate of Re. 1-2-0 per square foot, including cost of tack welding expanded metal. Actually 12,200 square feet of guniting varying in thickness from 1½" to 2½" (round corners) was done at an all-in rate of Re. 1-2-0 per square foot. The main details of the expenditure were as follows:—

Item.	Quantity.	Cost.
		Rs.
1. Cement ordinary	24.81 tons	894
2. Cement Rapid Hardening ..	38.45 ,,	1,774
3. Sika	357 gallons.	5,355
4. Sand	3340 c.ft.	167
5. Expanded metal	11370 c.ft.	1,509
6. Electrodes No. 10	2250 R. ft.	148
7. Fuels and lubricants for welding plants and compressors ..		880
8. Spare parts for the cement guns ..		34
9. Miscellaneous consumable stores ..		180
10. Depreciation of service material ..		105
11. Labour charges for welding and guniting. ..		2,451
	Total ..	13,497

A thorough inspection of guniting on this bridge was made recently. In a number of bents streaks of rust had appeared in certain places within a couple of feet of the top of the new plate girder bracings. On a closer examination it was clear that these streaks emanated from the ragged ends of the expanded metal which had an insufficient covering of gunite. Although the steel work was covered with 1½" thick gunite, the actual covering over the expanded metal varied from 1¼" to 1" only. This cover seems to be insufficient. This fact is further confirmed

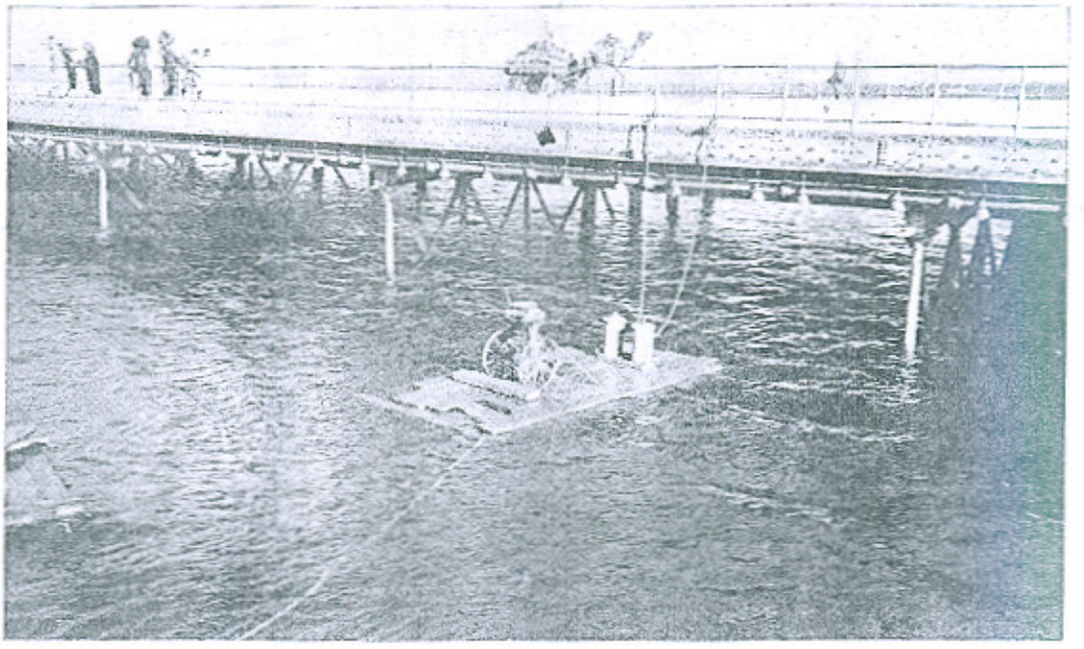
by the report of the Sea Action Committee in England. A summary of the report appeared in the *Engineer* in its issue of the 10th April 1936. It stated that a two-inch cover of concrete provided over the steel reinforcement afforded adequate protection against corrosion due to sea water. Considering that gunite is more impervious to water than ordinary concrete, it would appear that minimum covering of 1½" should have been provided over the expanded metal. If these rust streaks develop any further, the rusting and consequent expansion of the expanded metal may lead to cracking of gunite covering. Regular inspections of the work are being made. If any further development takes place, it is proposed to increase the covering of gunite at places where it is inadequate already.

Guniting certain piers of girder bridge No. 275 between Rohri and Khanpur.

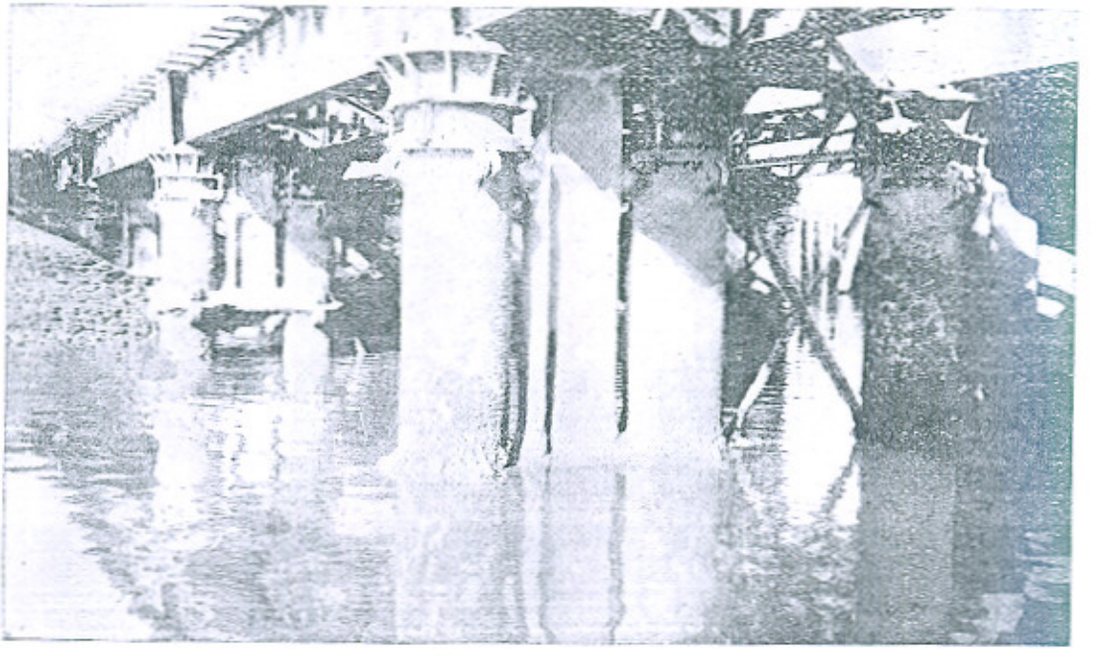
This bridge which consists of 12 girder spans of 40 ft. each resting on abutments and piers of brickwork, was the scene of an accidental fire in 1934 when sleepers carelessly stacked under the girders caught fire on account of a spark from a passing train. As a result of the conflagration the girders of four spans were badly damaged and had to be renewed. The brickwork of the five piers was burnt badly and got loose and flaky on the surface. Detailed examination showed that the brickwork was affected to a depth of about 3½" at a few places. In order to strengthen the masonry work and prevent its further deterioration from weathering it was decided to cover the affected brickwork by gunite.

The brick work which had lost its adhesion and strength due to the fire was completely removed by chisels, the surface was roughened and the mortar joints were raked to a depth of about 3/4". The surface was then thoroughly wetted for several hours before guniting was applied. The thickness of gunite varied from 1 to 3½" averaging to about 1½". A mixture of one volume of ordinary cement with three parts of Haro sand was used, about 20 per cent. of the sand in the mixture was lost due to rebound and was again used for further guniting. No reinforcement was used in this work.

When only a part of the face of a pier was left to be gunited, it became necessary to despatch the cement guns to the Chinna Creek Bridge at Karachi as the spring tides were due. Instead of guniting this area, it was carefully cement plastered by the old method. The thickness of the plaster varied from 1" to 1½". Not a single crack has developed on this area so far, although a few cracks appeared on the area, which had been gunited at places where the thickness of gunite exceeded 2½". The author is of opinion that these cracks in guniting would not have occurred, if the thickness of the layer of gunite had not exceeded 2 inches and that when it was necessary to have a thicker deposit, it should have been applied in two layers.



THE GUNITING EQUIPMENT ON A RAFT NEAR CHINNA CREEP BRIDGE



NEW BRACING GIRDERS PROTECTED BY GUNITE AT CHINNA CREEP BRIDGE.

On this bridge about 3668 square feet were gunited for which the total expenditure was as follows :—

		Rs.
1.	Labour charges including supervision charges ..	325
2.	Cement ordinary 12.65 tons at Rs. 36 per ton ..	455
3.	Sand 871 C.ft. at Rs. 6 per 100 C.ft.	52
4.	Fuel and lubricants for compressor and other consumable stores	76
	Total ..	908

This works out to about four annas per square foot.

Guniting of Khojak Tunnel 1928 to 1930.

The Khojak tunnel, about 2½ miles long, is situated about 70 miles from Quetta en route to Chaman. The roof of the tunnel used to leak badly every spring. In winter it looked like a perfect grotto as frozen water could be seen in the form of icicles which had to be removed every morning by the permanent way men before any train passed through the tunnel. As a result of the seepage aided by the heavy grade on the track, there was considerable slipping of the wheels and sometimes even stalling of the locomotive engines. Worse than this, the crew of the engines and the passengers were sometimes overcome by the fumes of the engine and the doctor stationed at Shellabagh—a station at one end of the tunnel had to treat cases of asphyxiation.

To overcome this problem, it was decided to gunite the inner surface of the tunnel wherever the water was leaking in small quantities. At places where the flow was too excessive to be kept back by guniting the seepage water was collected on galvanized sheet iron trays and channels securely bolted to the roof of the tunnel and drained off by suitably placed pipes into the central drain which runs between the two tracks in the tunnel. At the same time the existing weep holes were cleaned and made more effective and more weep holes provided.

The guniting work was started in May 1928 and completed the following year in November 1929. The work was done under the supervision of the late Mr. T. M. Walker who was then Sub-divisional Officer in charge of this section. Mr. Walker's keen interest in the work is amply borne out by the completeness of the notes left by him.

The equipment consisted of a cement gun type N-0 and a petrol driven air compressor.

The total area gunited during the two seasons amounted to 4,76,000 square feet. Places, where one layer of gunite did not prove effective in stopping the seepage, were treated with a second layer of gunite.

Before guniting, the joints in the brickwork lining were raked out to a depth of about ¾". The surface of brickwork was then sprayed with water under pressure. Where seepage was excessive, the brickwork was cleaned by hot compressed air and a rich mixture of gunite was shot almost dry to begin with. Except in these very damp places the mix consisted of one volume of cement to two volumes of coarse sand screened through 1/8 inch mesh before use.

The cost of guniting per hundred square feet was as follows:—

	Labour.	*Material.*
1. Scraping and cleaning brickwork including all arrangements for scaffolding	Annas 10.	Annas 6.
2. Cement guniting including lead of material to site ..	Rupee 1	Rupees 3.
3. Making weep holes, cutting and fixing old boiler tubes in the same and guniting round tubes and galvanized sheet iron trays	Annas 3.	Annas 3.
4. Miscellaneous expenses including repairs to tools and plants	Annas two.	
5. Carriage charges including charges for trucks and power for shunting ..	Annas two.	
6. Supervision charges	Annas six.	
Total	.. Rupees 6, *i.e.*, about -/1/- per square foot.	

From the notes it appears that in one season an area of 174,600 square feet was gunited with 5,870 c. ft. of concrete, The average thickness of gunite was about two-fifth of an inch and this point should not be overlooked while comparing the cost of this work with the works described already.

In the year 1930 seepage appeared at certain other places which had not so far been gunited and during that year these areas were treated with a coat of gunite about | inch thick and about 78,430 square feet were done.

For the next two years it was thought that the seepage trouble had been finally overcome. But as time went on the old trouble started again and it had to be admitted that the guniting had not been a complete success.

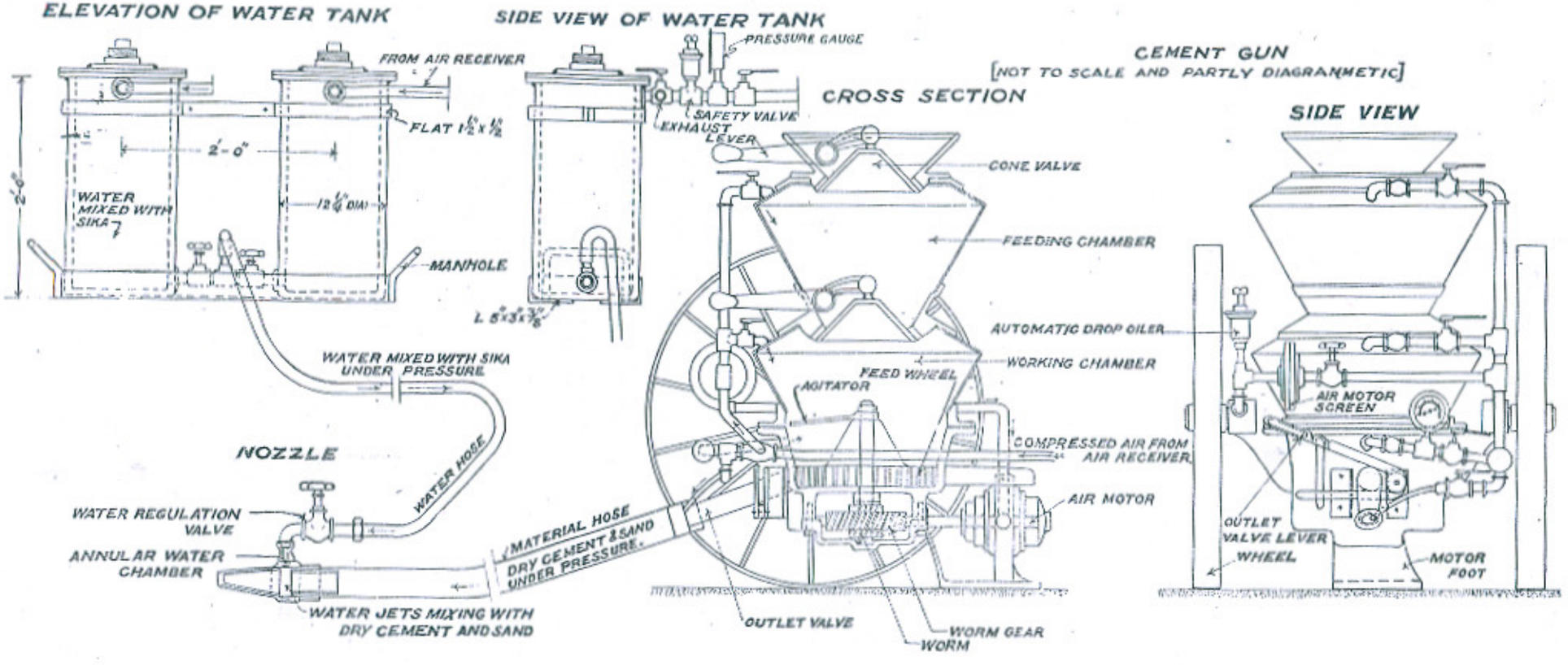
A careful inspection in 1933 revealed that in places where the seepage was considerable, the gunite had fallen off and was disintegrating. Where the gunite still held, heavy saline incrustations were observed. It was evident that the gunite had held back accumulations of water having salts in solution with the result that the brickwork had become thoroughly saturated and disintegration either by chemical action or by the mechanical action of freezing had set in. Slabs of gunite and brickwork became dislodged and so frequent did the falls of brick and gunite become that the warnings had to be issued to the staff working trains through the tunnel. The cure had actually proved worse than the disease. It has since been decided to experiment cement grouting the brickwork and it remains to be seen whether this will be more effective than guniting.

The failure of the guniting was due to the disintegration of the brickwork to which the gunite adhered. With the grout forced in behind the brickwork, there is every hope that the seepage may be kept back from the masonry which it will protect.

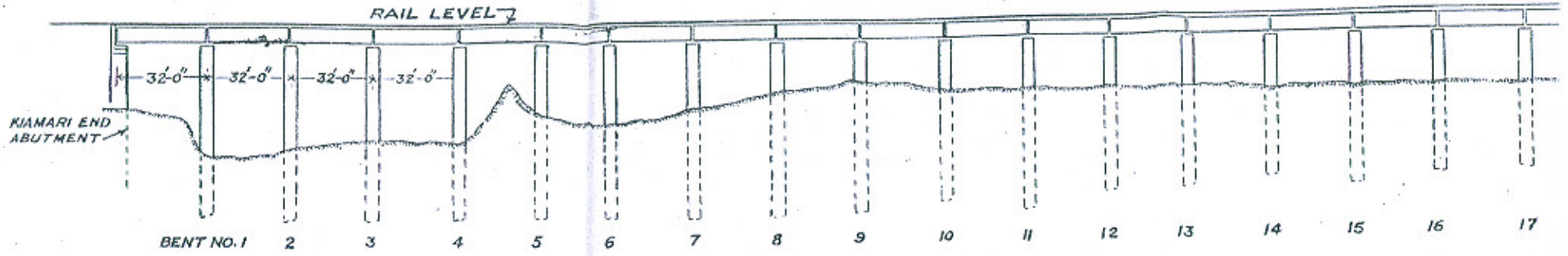
In the end the author expresses his thanks to Mr. P. S. A. Berridge, Executive Engineer, Bridges, for his valuable suggestions and for permitting him to use his photographs in this paper. The author is also grateful to Mr. F. R. Morgan, the Chief Engineer, North Western Railway, and Mr. H. Wood Robinson, the Deputy Chief Engineer, Bridges, for having permitted him to present this paper to the Punjab Engineering Congress.

PLATE I
PAPER NO. 203

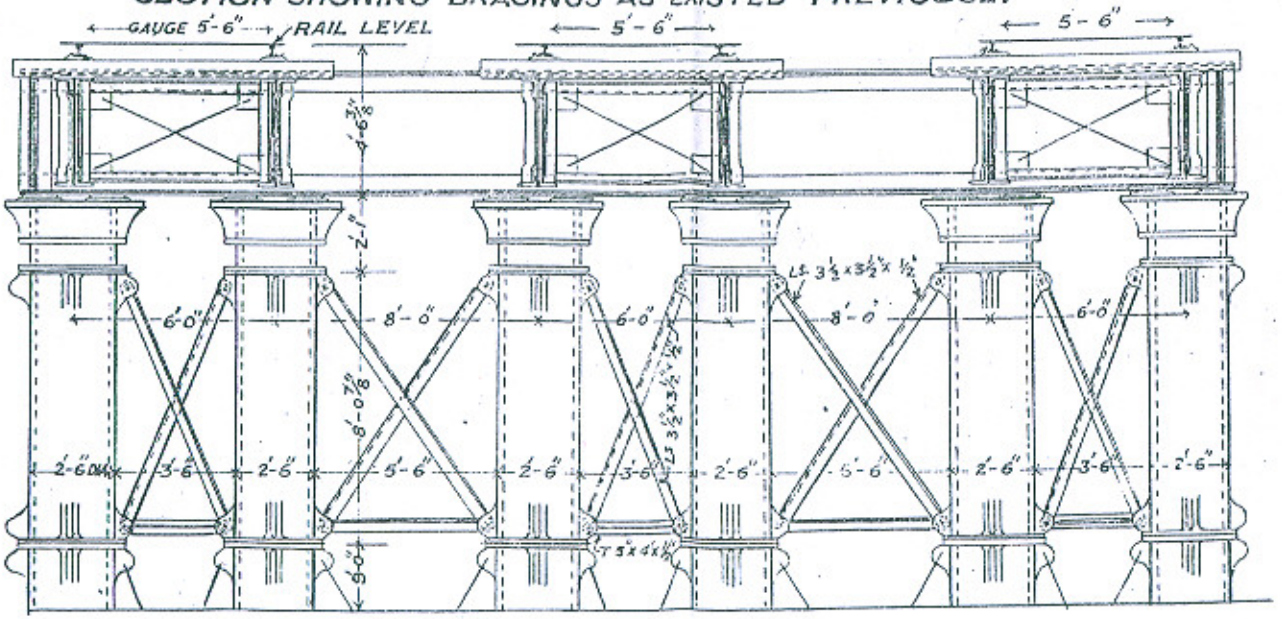
DETAILS OF THE EQUIPMENT FOR GUNITING



GENERAL ELEV



SECTION SHOWING BRACINGS AS EXISTED PREVIOUSLY



SECTION SHOWING ONE METHOD OF COI

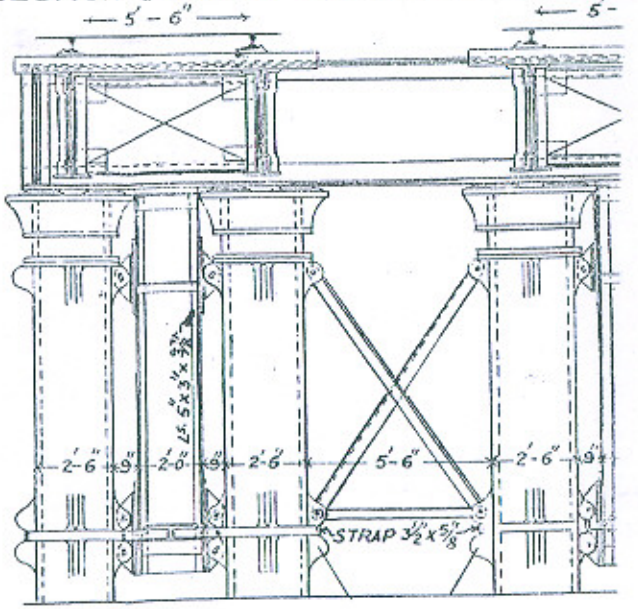


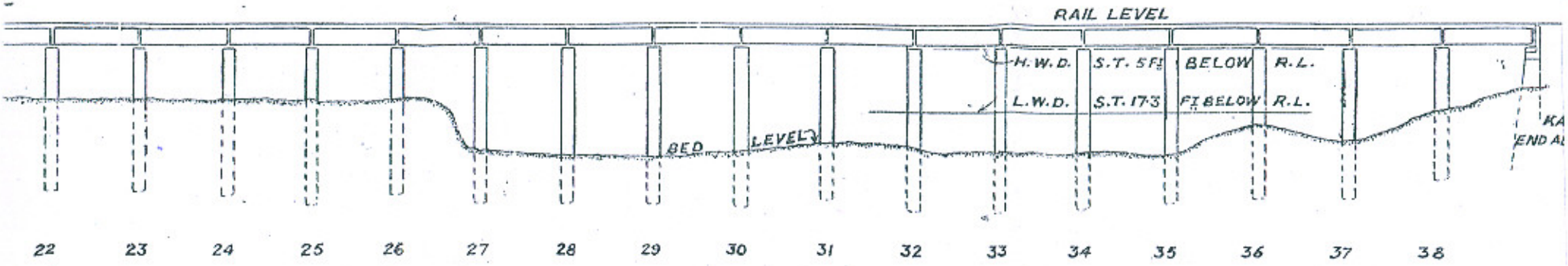
PLATE. II

PAPER NO 203

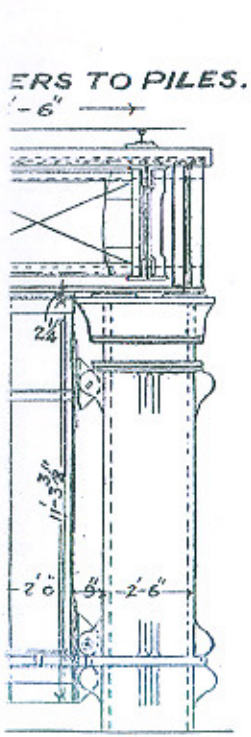
CHINNA CREEK BRIDGE AT KARACHI

DETAILS OF BRACINGS BETWEEN C. I. PILE BENTS

SCALE 3/16" = ONE FOOT.



SECTION SHOWING SECOND METHOD OF CONNECTING NEW BRACING GIRDERS TO PILES.



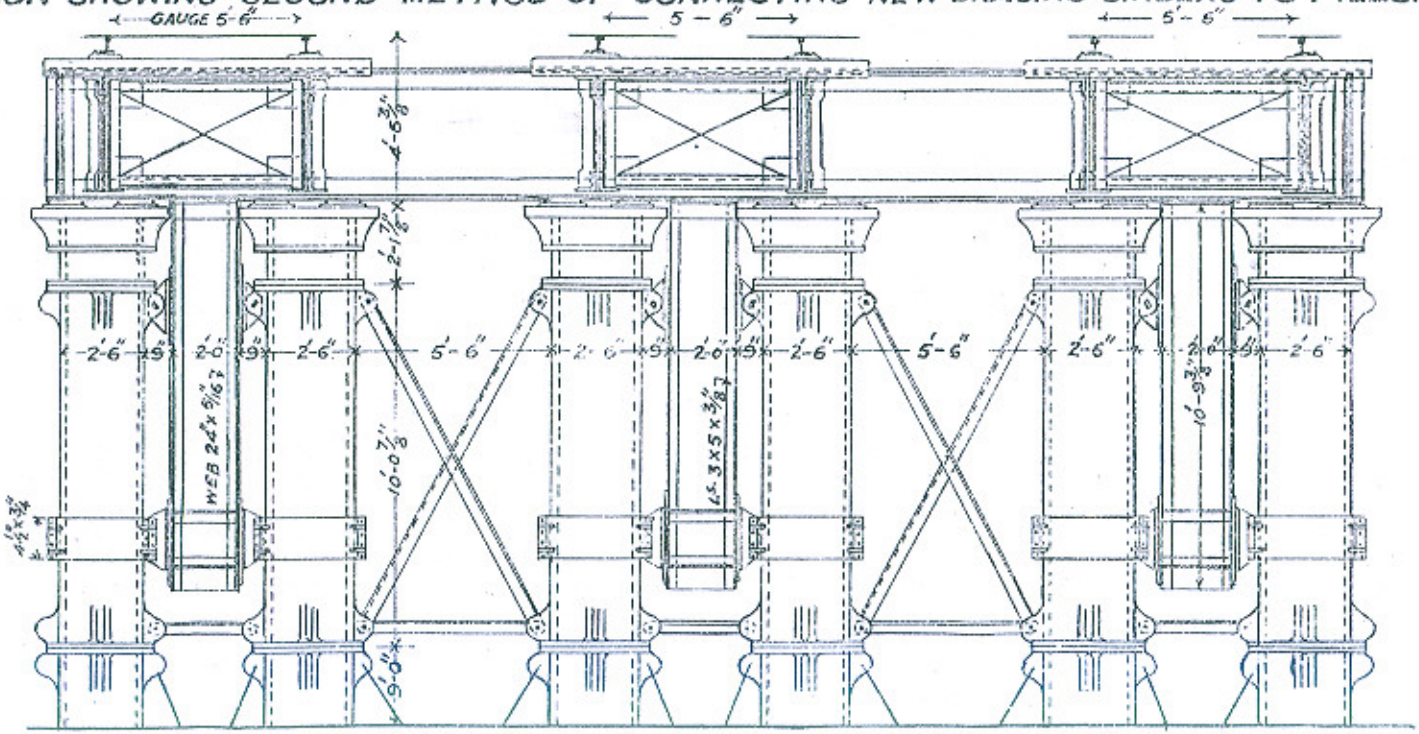


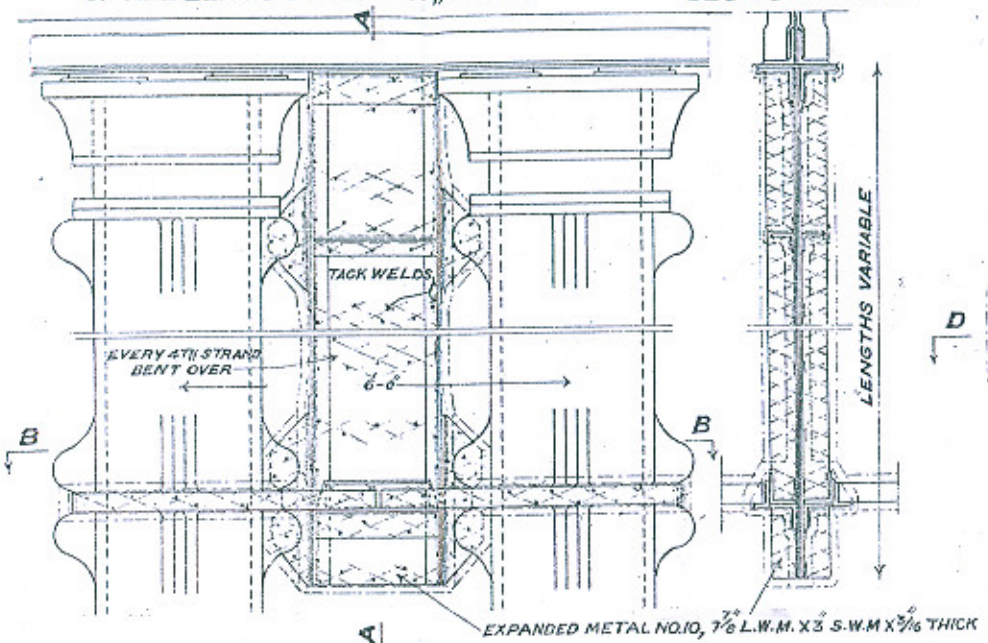
PLATE III
PAPER NO 203

CHINNA CREEK BRIDGE AT KARACHI

PRODUCTION FOR NEW BRACINGS BETWEEN PILES BY GUNITING

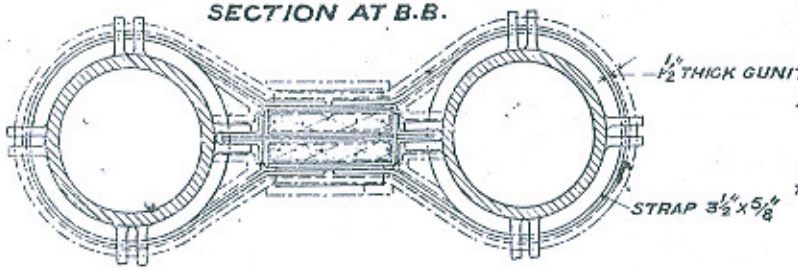
SCALE ½" = ONE FOOT

PART ELEVATION OF ALL BENTS EXCEPT Nos 12 TO 19

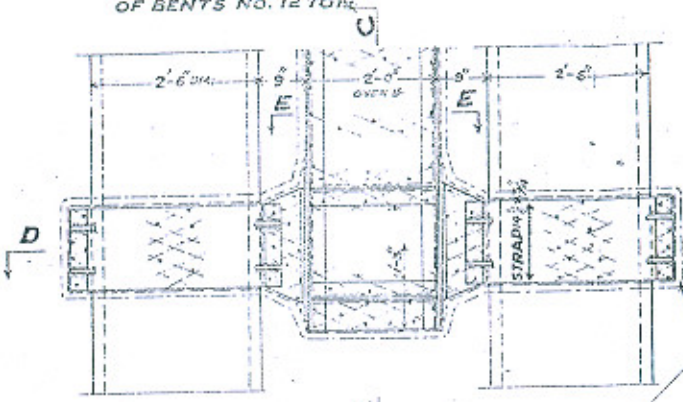


SECTION AT A.A.

SECTION AT B.B.



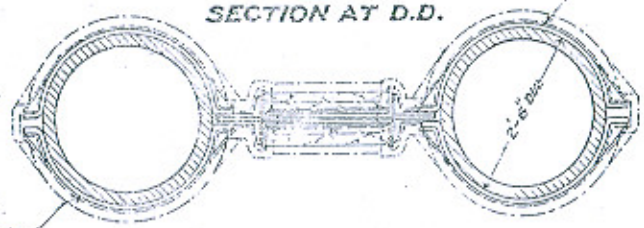
PART ELEVATION OF BENTS NO. 12 TO 19



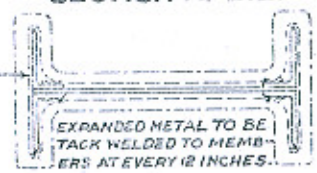
SECTION AT C.C.



SECTION AT D.D.



SECTION AT E.E.



DISCUSSION.

MR. **S. L. Kumar** in introducing his Paper said that guniting was well known in America and Europe, particularly in the former, where it is associated with almost all types of building construction, *e.g.*, masonry, earthwork, concrete, steel and timber construction. Besides its uses to the Civil Engineer, it could be of use to the Mechanical Engineer also. It was claimed that if a mixture of cement and powdered firebricks were shot through the gun, the resultant coating would be heat insulating and could, therefore, be used for lining high pressure boilers and furnace arches, steel and masonry chimneys.

Mr. Kumar said guniting was not so well known in India as it was at present a complete monopoly of Messrs. John Fleming & Co., Bombay who were prepared to execute gunite contracts in this country and Ceylon, but did not sell the cement gun. The North-Western Railway bought two guns some years ago when probably there was no restriction on their sale.

As had been explained in his Paper, the author said guniting had been fairly successful on all the works it was applied to on the North Western Railway, except in the case of the Khojak tunnel where it had been a complete failure. This was a case where to the author's mind it should not have been used. Guniting had not, however, yet been fully exploited on the railway, for it could be usefully employed for reconditioning thousands of bridges where, on account of efflorescence the disintegration of the brick-work was going on rapidly. A covering of unreinforced gunite after carefully removing the loose material, the author hoped, would cure the trouble.

Efflorescence, Mr. Kumar said, was largely due to the evaporation of the water carrying salts in solution derived from the foundation, back fill, brick or mortar, such evaporation taking place on the surface of the brick-work. Gunite being water-proof would stop this evaporation and thereby stop further quantities of water rising by capillarity or porosity of bricks to the surface of the brickwork. Rain and flood water carrying salts in solution would also be prevented from gaining entry into the work. Similarly, the author thought that on masonry bridges where the stone was badly weathered due to abrasive action of sand drifts on inferior quality of stone, acidic sulphur gases and carbon dioxide in air, minute fissures or cracks in stone, or due to frost, guniting could be effectively used to prevent further decay and deterioration.

MR. **Vidya Rattan** remarked that the author was to be congratulated on presenting to the Congress a Paper which was not only interesting but also instructive—interesting because to most of the listeners it came in a new way, for although gunite may have been

on the market 20 years ago, it had been heard of but little and used even less ; it was instructive because it claimed to possess certain outstanding advantages over ordinary hand-mixed mortar. It was instructive in yet another way because of the failure associated with its use.

Mr. Vidya Rattan said that gunite, as the author assured the audience, was nothing but a mixture of cement and sand in the form of cement plaster with which all engineers were so familiar ; only in this case the cement plaster was used under pressure. According to the author, gunite was about $2\frac{3}{4}$ times as strong as the ordinary hand mixed plaster. What was it that gave to gunite this extra strength ? The speaker greatly wished that the author had dealt with this question rationally and in greater detail than by telling the audience in a casual way that this increased strength came from lower water-cement ratio. Lower water-cement ratio was certainly one of the contributing factors but it was not the only one ; for if it were possible to mix cement and sand by hand using the same quantity of water per bag of cement as in the case of gunite it was highly doubtful if the same strength could be obtained. It was the low water-cement ratio as well as the thorough mixing of cement and sand under pressure resulting in a more complete filling of the interstices of sand with cement that gave to gunite extra strength—in other words the increased density of gunite. Density was a measure of strength and was proportional to it. The author did not say what was the density of gunite relative to cement plaster nor was there any mention whether any density tests were taken in the 3 cases cited by the author. This was according to Mr. Vidya Rattan, a very important omission. It was more than likely that for the same mixture of cement and sand in gunite, the cement-water ratio and the pressure of ejection could be varied so as to produce gunite of varying densities. The usefulness of carrying out density tests as enabling one to determine the best mixture could not be too strongly emphasized.

Adverting to page 92, Mr. Vidya Rattan said that one of the chief uses claimed for gunite was, "encasing steel work which is already corroded or new steel work to prevent corrosion, particularly under difficult conditions such as obtain in structures submerged in sea water or exposed to strong sea breezes."

Mr. Vidya Rattan continued that finding a suitable hydraulic product to act as protection against the destructive action of sea water had been to this day a much vexed question. Unfortunately, from what little the author had said in his Paper it was difficult to agree that gunite was the answer to that question. Only one instance of its actual use under such conditions had been given—*viz.*, the Chinna Creek Bridge and the results of even that limited experience were far from gratifying.

To begin with gunite had not been used alone. It had been used in combination with Sikka so that the special suitability of gunite even though corrosion were definitely stopped, would still remain doubtful. But when, however, as was apparent, the combined effect of gunite and Sikka had failed to combat the action of sea-water there was nothing more to be said. On page 102 it was admitted that in a number of bends "streaks of rust had appeared in certain places within a couple of feet of the top of the new plate-girder bracings," although the steel work was covered $2\frac{1}{2}''$ at the corners.

To quote the words of the author, "many a well-advertised and well known special point had had its reputation wrecked when tried at this bridge." Could the author say that gunite had had better luck?

Speaking on the theory of the problem Mr. Vidya Rattan continued that the decomposing action of sea water was due to the presence of dissolved sulphate, chiefly magnesium sulphate. These acted on the Aluminate of Lime in the Portland Cement forming sulpho-aluminates which produced the swelling causing the disintegration. The whole problem was to stop this reaction which was entirely chemical or in other words how to exclude the Aluminate of Lime in Portland Cement without diminishing its strength or affecting its setting or hardening properties. Mr. Vidya Rattan entirely failed to understand how gunite which did not contain any different composition of Portland Cement could arrest the chemical action referred to above.

Another of the advantages given by the author of the use of gunite was in regard to its special suitability for re-lining steel and masonry chimneys. There was no doubt that by this the author meant that gunite had better heat and fire resisting properties, but the author had not illustrated his point by giving any concrete instances nor supported it by scientific analysis. The heat resisting properties depended on two things:—

(1) Water contained in the cement.
(2) Porosity.

With regard to (1), at high temperatures much above the boiling point of water the water in the cement went off but it was not until the dehydration was complete and this occurred at 800° to 900° that the heat could be transferred to the steel or the masonry of the chimney. It could not be argued that Gunite could be better than plaster because the percentage of water in chemical combination with cement was the same in both cases. With regard to the porosity, however, the argument was different. Gunite because of its lower water-cement ratio and a more complete filling of the interstices of sand with cement was much denser than hard mixed mortar. That meant it was less

porous and therefore conducted heat more rapidly. When such was the case Mr. Vidya Rattan could not understand how gunite although less heat-insulating was recommended in such situations.

Lastly, Mr. Vidya Rattan said that for the benefit of the Irrigation Engineer the author had suggested the use of gunite for lining Irrigation Channels. The question of cost which such use entailed precluded the possibility of its general adoption. To illustrate, the charges for 1" gunite unreinforced are Rs. -/10/- per °/₀ sq. ft.; for 1½" it was going to be some where near Re. 1. The author's own figure was Rs. -/4/- per °/₀ sq. ft., but he did not take into account, depreciation, etc. Be that as it may, it could not be seriously disputed that gunite was at least 3 times as costly as cement plaster of the same thickness. Knowing how precious a cusec of water is, and how much of it is wasted through absorption in earthen channels, the high cost of lining even with cement mortar had stood in the way of its general adoption and when this was increased three times, such a luxury became definitely out of the question.

Mr. **Inder Sen** remarked that, as given on page 98, Sika was used on Chinna Creek Bridge. The use of Sika when mixed with water was claimed to make the concrete set more quickly and render it impervious to water. This costly article, the speaker said, was tried by him in 1931 and found not as useful as it was advertised to be. Fearing that he may not have used it properly he wrote to the suppliers at Lahore about what he thought of Sika and asked them to send an expert who could demonstrate its proper use. He got the reply that the suppliers could neither find any fault with the method used by the speaker nor had they an expert for its proper demonstration.

As reported in the Paper, 357 gallons of this article at a cost of Rs. 5,355 had been used on Chinna Creek Bridge and when they ran short of it, they used Rapid Hardening Cement instead on the major part of the work.

The speaker gave a comparative statement of costs of this work (see page 105*e*) and said that all costs were included in these figures.

From the figures given, the speaker showed that it was much cheaper to use Rapid Hardening Cement than to use Sika with ordinary cement. The use of Sika made the work 2½ times as costly as the use of Rapid Hardening Cement, and probably with the better results. Sika alone cost about 65 p.c. of the total estimated amount of the work.

For the reason of cost alone Mr. Inder Sen thought that it was worth consideration whether Sika should be used with ordinary cement or simply Rapid Hardening Cement on works of this nature. He

(1) *Ordinary Cement with Sika.*				(2) *Rapid Hardening Cement without Sika.*			
	Item.	*Quantity.*	*Cost.*		*Item.*	*Quantity.*	*Cost.*
			Rs.				Rs.
1.	Cement ordinary	63·26 tons	2,278/-	1	..	..	..
2.	Cement Rapid Hardening	..	..	2	..	63·26 tons	2,918/-
3.	Sika	913 Gal.	13,695/-	3	..	..	..
4.	Sand	3,340 c.ft.	167/-	4	..	3,340 c.ft.	167/-
5.	Expanded Metal	11,370 c.ft.	1,509/-	5	..	11,370 c.ft.	1,509/-
6.	Electrodes No. 10	2,250 R.ft.	148/-	6	..	2,250 R.ft.	148/-
7.	Fuels and Lubricants for welding plants and compressors.	..	880/-	7	..	..	880/-
8.	Spare parts for the cement gun ..	..	34/-	8	..	..	34/-
9.	Miscellaneous Consumable stores ..	..	180/-	9	..	..	180/-
10.	Depreciation of service material ..	..	105/-	10	..	..	105/-
11.	Labour charges for welding and guniting ..	..	2,700/-	11	..	..	2,200/-
		Total ..	21,696/-				8,141/-

suggested the use of Rapid Hardening Cement and if need be, given a second or thicker layer of gunite.

The **Author** in replying to the discussions, said that Mr. Vidya Rattan had somehow formed an impression that guniting used on the North Western Railway had been a failure. As a matter of fact, except on the Khojak tunnel where gunite was not to blame for its failure, guniting had been quite successful. Further damage to gunite at Chinna Creek Bridge where streaks of rust had appeared, could be prevented at a cost of a few hundred rupees by providing an additional cover of gunite.

Guniting required great skill and care and adequate supervision. Considering that the guniting on the North Western Railway was done by a staff who had had no previous experience of this work, the success attained in guniting had been beyond the expectation of even the firm who monopolize guniting in India.

Whether guniting had been successful or not on the Railway, it was wrong to condemn it wholesale, as the author had read several reports, in technical journals of its successful use in foreign countries. Further, whether guniting was a permanent prophylactic against the destructive action of sea water remained yet to be seen, but the author was sure that on the Chinna Creek Bridge, it would serve its purpose for a very long time. Even if it served for ten years, its cost could be justified on economical grounds. It was due to its impermeability to water that the chemical action between the sulphates in the sea water and the aluminate of lime in cement referred to by Mr. Vidya Rattan either did not take place or took place at a very slow rate.

The increased strength of the gunite was due to its lower water-cement ratio, its great density and its superior adhesion to the surface it was applied to. In ordinary cement plaster work fine air bubbles were locked up in the process thus vitiating intimate contact between the mortar particles and surface plastered. The gradual building up of a layer of gunite expelled all air and the successive particles of cement and sand, impinging under pressure on those previously deposited, compacted the whole mass and ensured better adhesion. If Mr. Vidya Rattan were to try to mix cement and sand with the same water-cement ratio as had been used in guniting, the resulting mortar would not be capable of being worked with a trowel. The author regretted that no density tests for gunite had been made but promised to make them whenever an opportunity occurred.

The author had already stated in his introductory remarks that for lining steel and masonry chimneys or furnace arches, ordinary gunite was not used but a mixture of cement with powdered firebricks were shot through the cement gun. The resulting mixture had been found to give

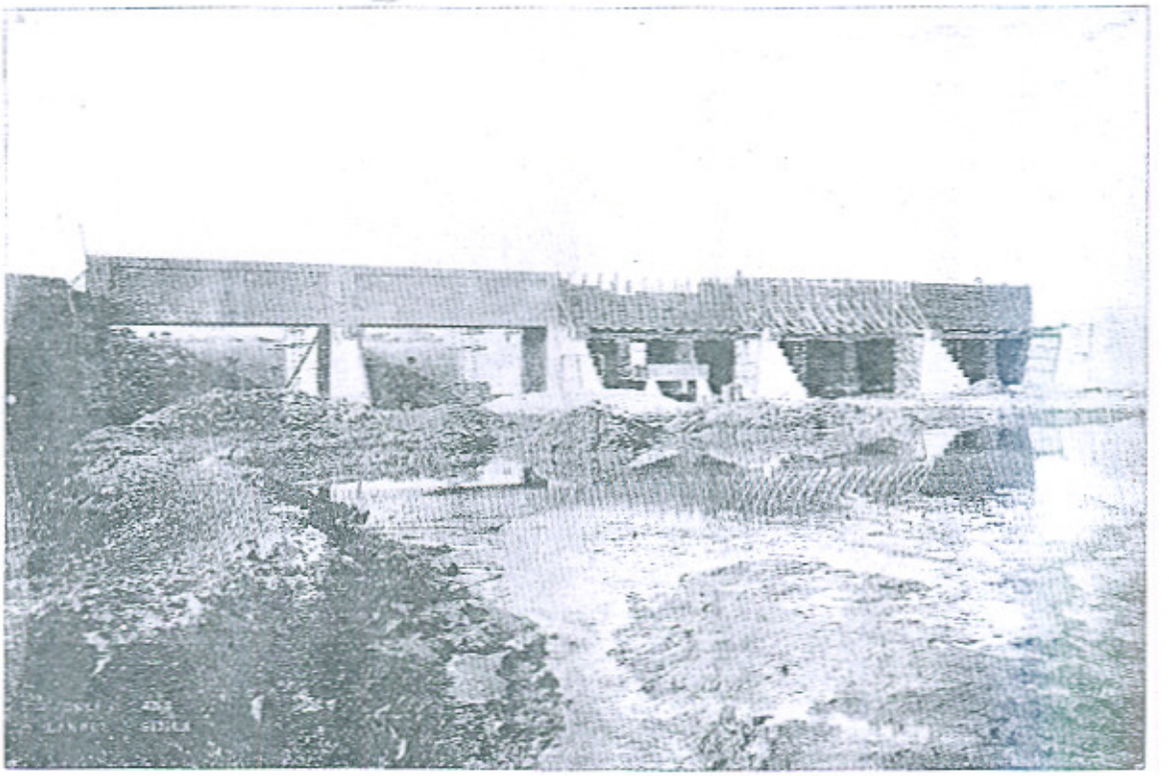
adequate insulation against heat in other countries. The author having never tried it personally could not vouchsafe for the accuracy of this claim.

It was obviously unfair for Mr. Vidya Rattan to compare the cost of 1" or 1½" thick gunite with a similar thickness of cement plaster in connection with the lining of irrigation channels, as the latter could not be equally effective against seepage of water from these channels.

Regarding the criticism of Mr. Inder Sen the author remarked that he was inclined to think that, as a result of the experience gained at the Chinna Creek Bridge, Rapid Hardening Cement used alone for guniting would have served the purpose and very little Sika, if any, need have been used.



OLD DEG HEAD.



THE DEG FALL AND AQUEDUCT.