CHAPTER (4)
EXPERIMENTAL WORK

4-1 The Objective

The objective of this work is to investigate the effects of shielding phenomenon applied to steel sheet pile protected from one side (sea side) as some designers do [121].

The sheet pile is simulated by a steel plate (laboratory scale). The description of the experimental apparatus is given in the following.

4-2 Experimental Set up

To achieve the aim of the present work an experimental set up was constructed and proper instruments were used to measure the required parameters. The set up consisted of: three identical steel plates, 150 coupons, three separate basins, three anodes, salt water (electrolyte), two digital scales, two electrodes and a DC power supply with the required wiring connections. Figure 4.1 is a schematic diagram showing the main features of the experimental test set up showing the three basins, three plates, three anodes, electrolyte, DC supply, measuring electrode and instruments.

The description of the experimental set up components is summarized in the following subsections.

3-2-1 The Basins

Three separate basins were built inside doors in the same laboratory to ensure same external environments of the testing. The inside dimensions of each basin were 2×1×1 m. The basins walls were built using conventional bricks, coated with specially waterproof cemented

past. Waterproof insulation material was applied to the basins over all inside walls and the bottoms. Further, the inside walls and bottoms of the basins were lined with ceramic tiles. Each basin was also provided with a water drain with well sealed drain block. Photo 4.1 shows the general view of the three basins.

4-2-2 The Steel Plates

Three identical plates cut from the same, locally produced, cold rolled steel sheet material (DIN 1623) were used in the experimental work. The dimensions of each plate were 800×800×1.4 mm. 25 evenly spaced holes $^{\phi}4$ mm were drilled into each plate to allow the fixation of 50 coupons onto the two sides of each plate to monitor the corrosion patterns [122]. Another three holes were also drilled into each plate as shown in figure 4.2. The two holes 4^{ϕ} mm in line with the top raw of coupons holes and midway between the coupon hole close to the plate edge and the adjacent hole were used to allow the suspension of the plate in the vertical position. The third hole 2^{ϕ} mm was used to allow the attachment of the electric wire used in the plate/electrolyte potential measurement.

The plates were coded X, Y and Z, lightly sanded, cleaned using diluted HCl and thoroughly washed by fresh water. Prepared coded coupons were then fixed onto their corresponding plate faces by using plastic bolts and nuts (size M4). Electric wires were threaded through their holes and solder weld was used to ensure the proper electric connection. Drain and potential measuring cables were attached to each plate through the insulated welds.

Three wooden beams were placed on the top of the three basins as provisions to suspend the plates vertically in the middle of their basins.

Plastic ropes of same lengths were threaded through the two suspension holes of each plate. The ropes lengths were adjusted in order to ensure same distance between each plate and its corresponding basin bottom. The distance was about 5 cm above the basin bottom.

Photos 4.2, 4.3 and 4.4, show the view of the three plates at the end of test period.

4-2-3 The Coupons

The coupons were made from the same steel sheet material in the form of washers (20 mm outer diameter, 4 mm inner diameter and 1.0 mm thickness). A special punch was made to cut out the coupons from the steel sheet. Also, special six wooden plates were provided with nails fixed on them to receive the coupons. Each wooden plate has 25 nails and arranged in rows and columns similar to the arrangements of the coupons when fixed on the steel plates. Each nail was given the same code of its corresponding coupon. Photos 4.5 show the coupons on the coded plates.

Coded coupons were then thoroughly cleaned, dried and weighed before installation according to code of practice set by the **NACE** [123]. Each two opposite coupons were then fixed with a plastic bolt and a nut onto the surfaces of its plate according to their code. The wooden plates were used again at the end of the experimental work to avoid any mistake of mixing the coupons together.

At the end of the experimental works the coupons were unfastened one pair at a time and each coupon was placed on its coded place on the wooden plates. Weights of each coupon were recorded just before cleaning and after cleaning with diluted HCl, thoroughly washed with fresh water and dried.

4-2-4 Coupons and Plates Cleaning

Before testing, coupons and plates were carefully and slightly sanded with sand paper grade #150 to remove rust and deposits; then cleaned with a diluted (9 wt%) HCl to remove any greasy substances; thoroughly washed in fresh water several times to remove any traces of HCL [124].

On the other hand, at the end of the test period and unfastening the coupons and removing the electric wires, the plates were dried, visually examined, lightly sanded, re-cleaned, re-examined, cut into approximately equal parts and weighed.

4-2-5 The Electrolyte

To simulate the sea water, a commercial salt (NaCl) is used with fresh water to form the required electrolyte. The concentration of the solution was 2.5 wt% and prepared in a special container to ensure the full mixing of the salt with water and have the same electrolyte initial properties for the three basins. Each basin was filled with the prepared electrolyte to the level 5 cm above the plate top. Since the test lasted for a period of six months, electrolyte levels in the three basins were adjusted periodically by adding fresh water to compensate for the natural evaporation.

4-2-6 The Anodes

Three identical scrap steel anodes were used to impress the protection current: one anode for Plate-Y and two anodes for Plate-Z. figure 4.3 Shows the dimensions of the anodes where it was made in a cylindrical shape of ϕ80 mm in diameter and 60 mm in length with a cylindrical recess in the middle of length 40 mm. the middle part has a diameter of 40 mm. Briefly, the anode consists of two discs □80 in

diameter and 10 mm in length integrated with the middle square cylinder of $^{\phi}$40 and length 40 mm. a $^{\phi}$2 mm hole was drilled in the middle cylinder to receive the electric wire which was welded to the anode.

Each anode was covered by insulating coating from all surfaces except the surface facing the corresponding protected plate. The anodes coated surfaces were cleaned and primed before coating. The primer consisted of Araldite 1011 and Hardener 1011 (CIBA GAPY) mixed together in the ratio 3 Araldite to 1 Hardener by weight, diluted by Methel Ethel Kayton in ratio 10 : 20 %, then brush painted with a layer thickness of 50 μm and finally dried for 6 hours. While the coating consisted of mixture of Araldite 257, Hardener 830 and Hardener 850 in ratio by weight 100, 45 and 15 respectively. The coat thickness was 1.5 mm and the drying time was 8 hours

The three anodes were dried and weighed before installation. The anodes were connected to the positive side of the DC power supply by equal lengths of the same type and gauge of electric wires. Anode (1) was fixed onto the inside wall of basin facing the center of Plate-Y front. Anodes (2) and (3) were fixed in a similar way facing the front and back of plate-Z, respectively. The three anodes were dried and weighed at the end of the test period in order to find their individual material loss. Photo 4.6 shows the three anodes at the end of the test period.

4-3 Electrical Wiring and Equipment

A proper insulating wires and adjustable DC voltage and current supply were provided for the system. The DC supply was obtained from the domestic 220 VAC supply through a step down transformer and integrated full bridge rectifier and voltage regulator [124]. A schematic

diagram of the electric wiring is shown in figure 4.4, measuring points of the volt and current are shown on the diagram. Voltage and current were measured and recorded daily. The general view of the DC power supply is shown in Photo 4.7.

4-3-1 The Wires

Electrical wires of high quality $^{\phi}1$ mm diameter are used for all the connections. Equal lengths are used for each plate.

4-3-2 The DC Supply

A constant stable DC supply was obtained through a stabilized, electronically controllable power supply with power-IC. The voltage range was 1.2 - 30.0 V and the current was 2.0 A. A 24 V/2A transformer was used to step down the domestic power supply of 220 VAC source to the required DC range.

4-3-3 The Electrodes

Two electrodes were used to monitor the plate/electrolyte potential difference of the three plates. The electrodes type was $Cu/CuSO_4$ half cell electrode [125]. The first electrode is short, 150 mm in length, while the second is long, 750 mm. Figure 4.5 shows the schematic drawing of the short electrode. All dimensions of the long electrode are identical to that of the short electrode but its length is 750 mm. Photo 4.8 shows the two electrodes.

The short electrode was used to monitor, daily, the plate/electrolyte potential difference for the three plates. The potential difference was measured for each plate from both sides (front and back). The measuring point facing the front surface was a mirror image of that facing the back

surface. The distance of the measurement point from the plate surface was 450 mm and was laid in the perpendicular plane passing through the plate middle plane at 120 mm under water surface. Plywood beams with marked signs placed on the walls of the basins were used as fixtures to ensure that the measuring points are the same for all measurements.

The long electrode was utilized to monitor the plate/electrolyte potential difference for Plate-Y from both sides. The monitoring was carried out, approximately every two weeks. The measurements were carried out in planes perpendicular and parallel to Plate-Y surfaces. The measurements were taken along the vertical plane perpendicular to Plate-Y middle plane from the front and back sides at 18-points/side as indicated in figure 4.6. The measurements in the parallel planes were taken at 25 mm from the corresponding plate surface at 16-points/side as indicated in figure 4.7.

4-3-4 The Multimeter

A high quality digital multimeter, KYORITSU, is used to measure the electric resistance, voltage and current. The display is automatically adjusted to give the highest resolution and accuracy according to the value of the imposed parameters.

4-3-5 Electronic Digital Scales

High precision scales (up to 4 digits accuracy) were used to measure the weight of each coupon, anode, plate and plate part. The weighing was carried out before and after the experiments. Plate parts were also weighted at the end of the tests.

4-3-6 Plates Sample Analysis

At the end of the experimental work, 4 samples were used for electronic photography and components spectrum using X-ray to determine the effects of the cathodic protection on the surfaces of the three plates. One sample was taken from the same sheet material (reference sample) and three samples cut from plate-X, plate-Y and plate-Z, respectively.

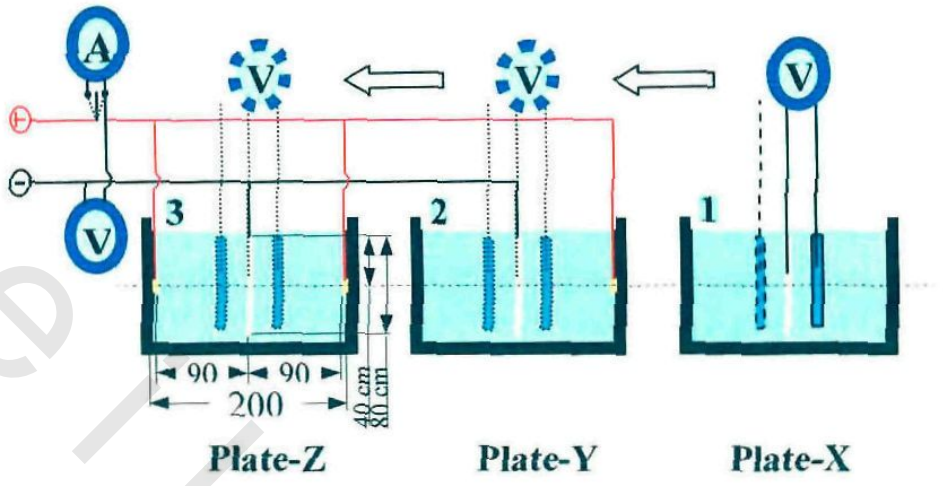


Figure 4.1 A schematic diagram showing the main features of the experimental test set up showing the three plates, anodes, basins, electrolyte, DC supply, measuring electrode and instruments.

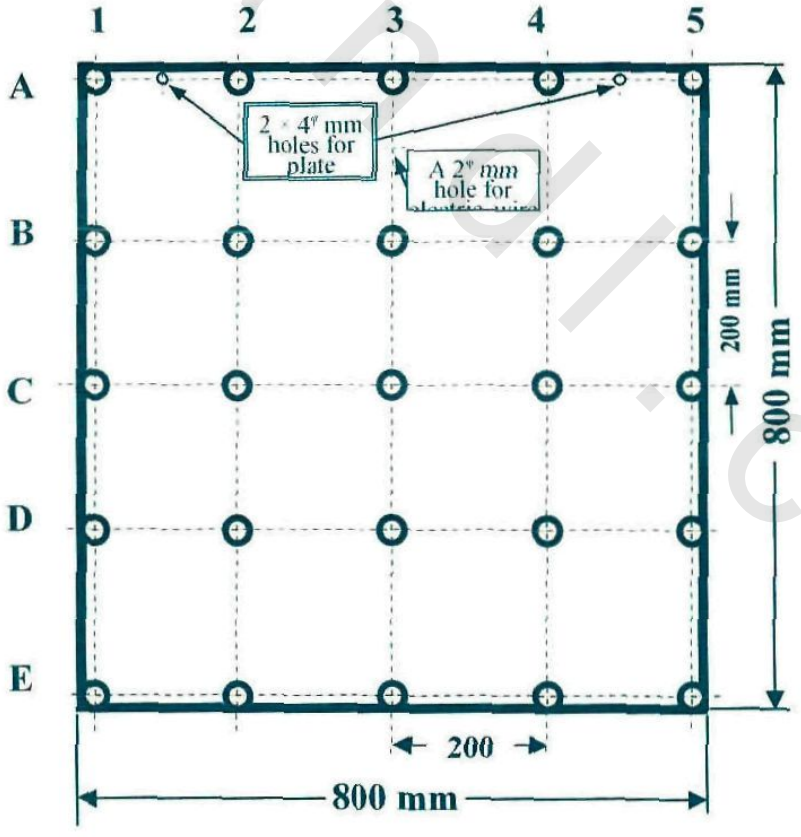


Figure 4.2 Distribution of coupons on the plate surface

Photo 4.1 General view of the three basins X, Y and Z

Plate X front

Plate X back

Photo 4.2 Plate-X at the end of testing (front and back)

Plate Y front

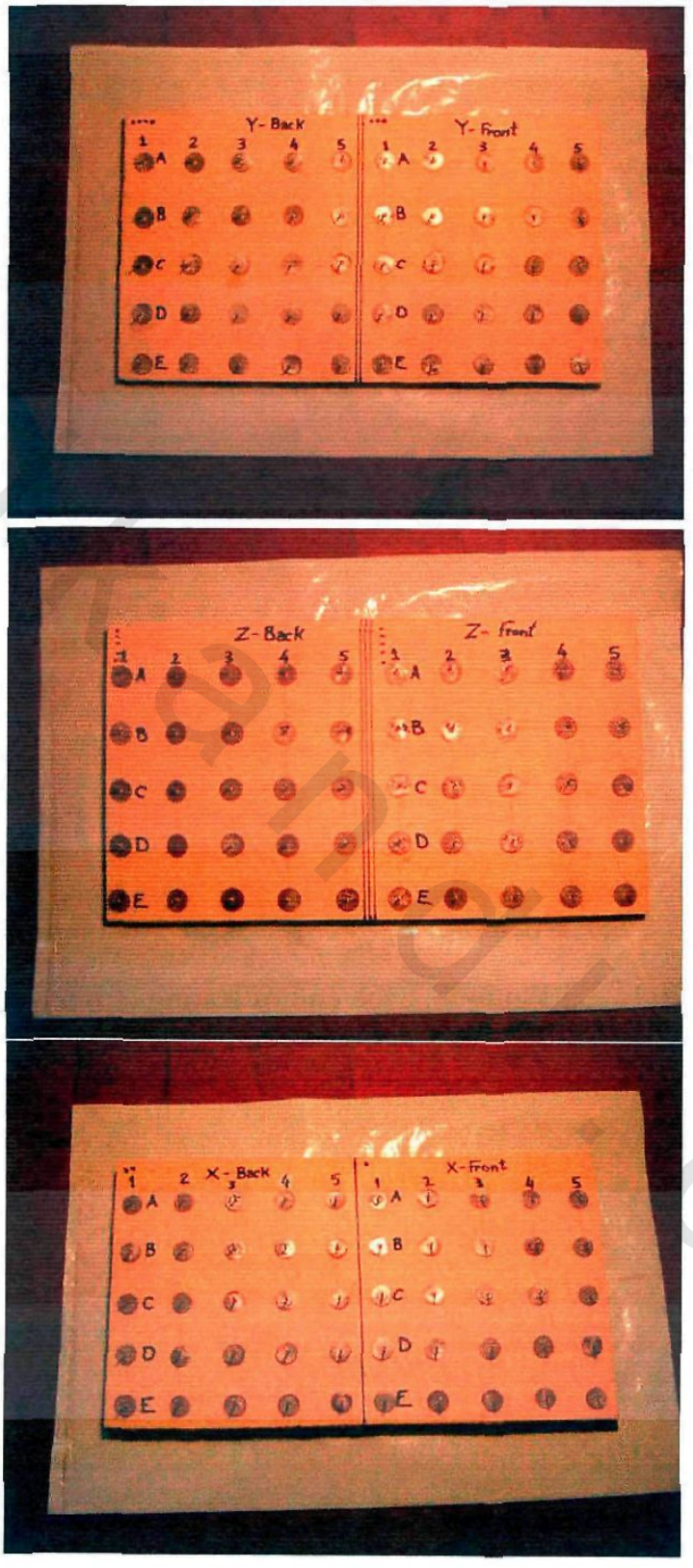
Plate Y back

Photo 4.3 Plate-Y at the end of testing (front and back)

Plate Z front

Plate Z back

Photo 4.4 Plate-Z at the end of testing (front and back)



Photos 4.5 the three sets of coupons on their wooden plates

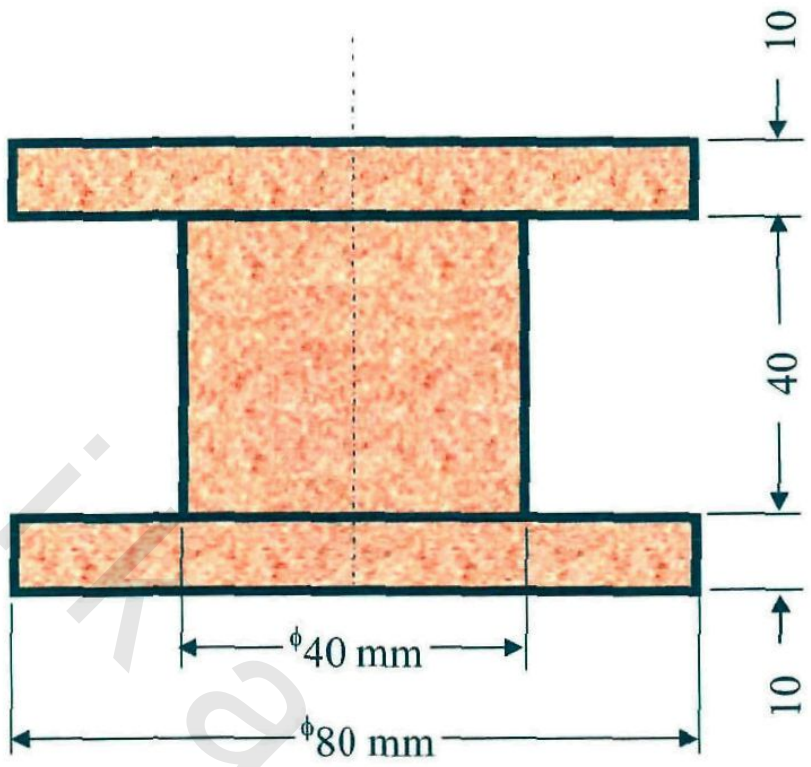


Figure 4.3 the dimensions of the anodes

Photo 4.6 The three anodes at the end of testing and the multimeter

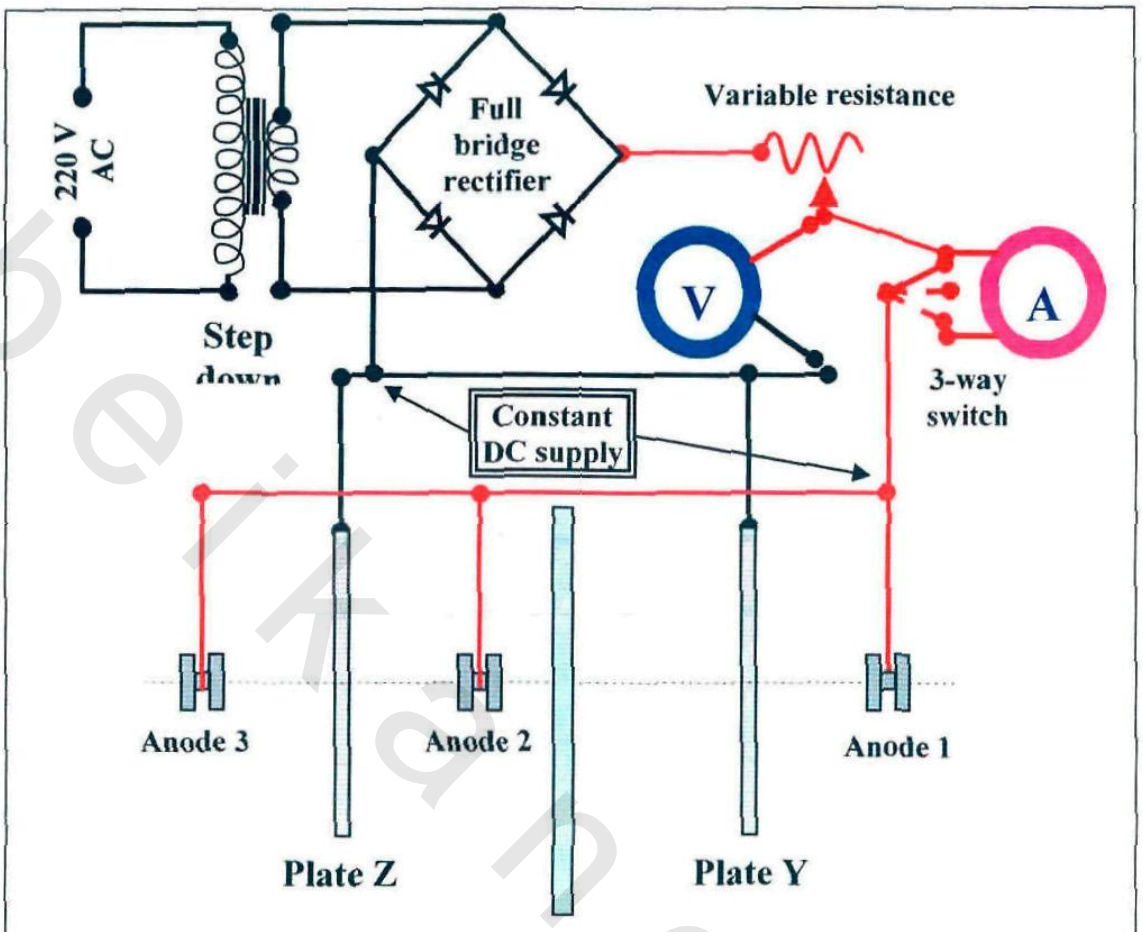


Figure 4.4 Electric circuit diagram of the impressed CP current

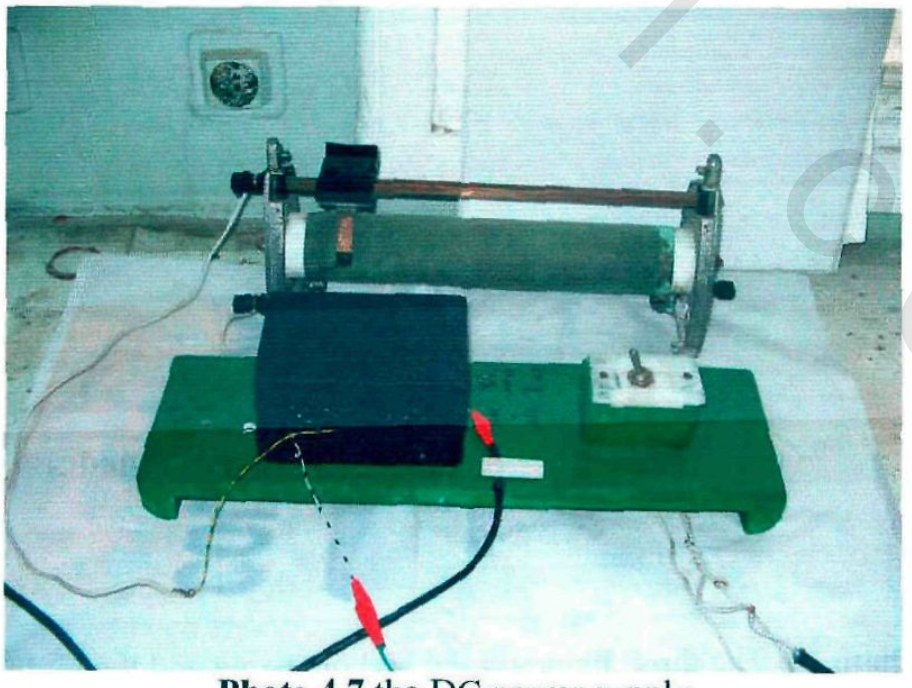


Photo 4.7 the DC power supply

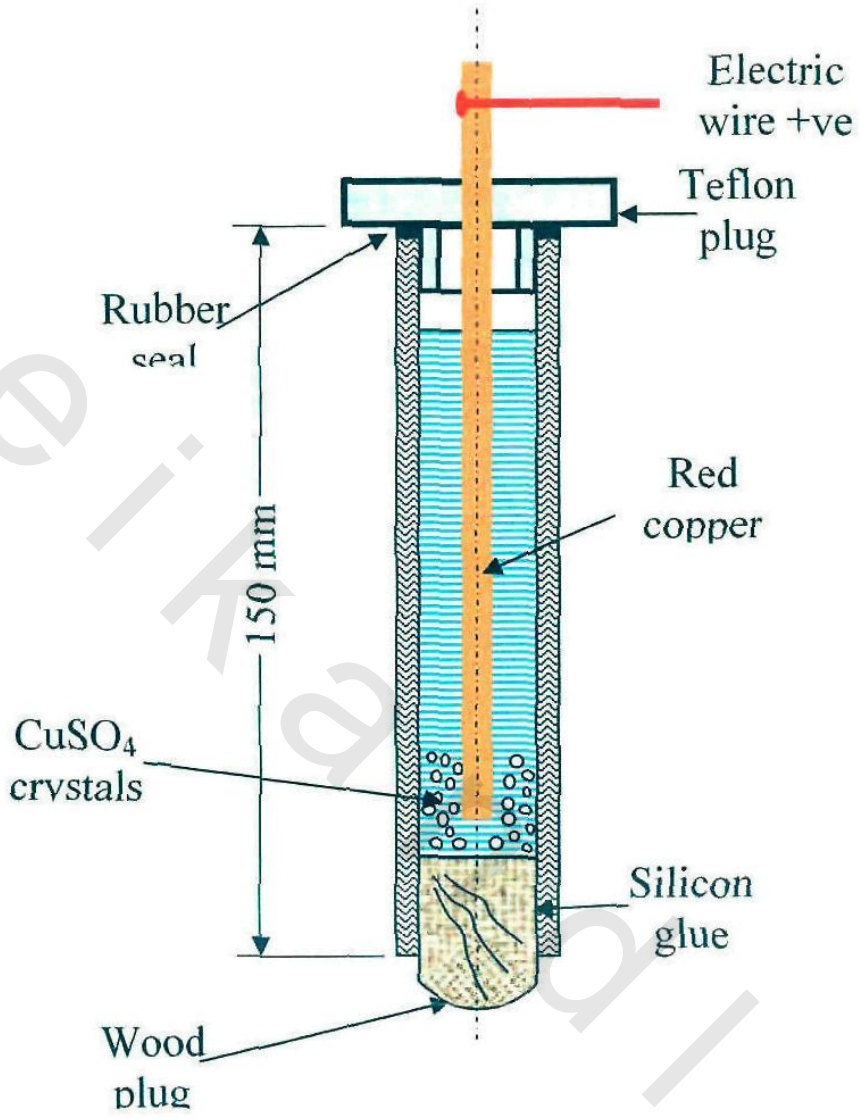


Figure 4.5 The short electrode, 150 mm length.

Photo 4.8 The short and long electrodes

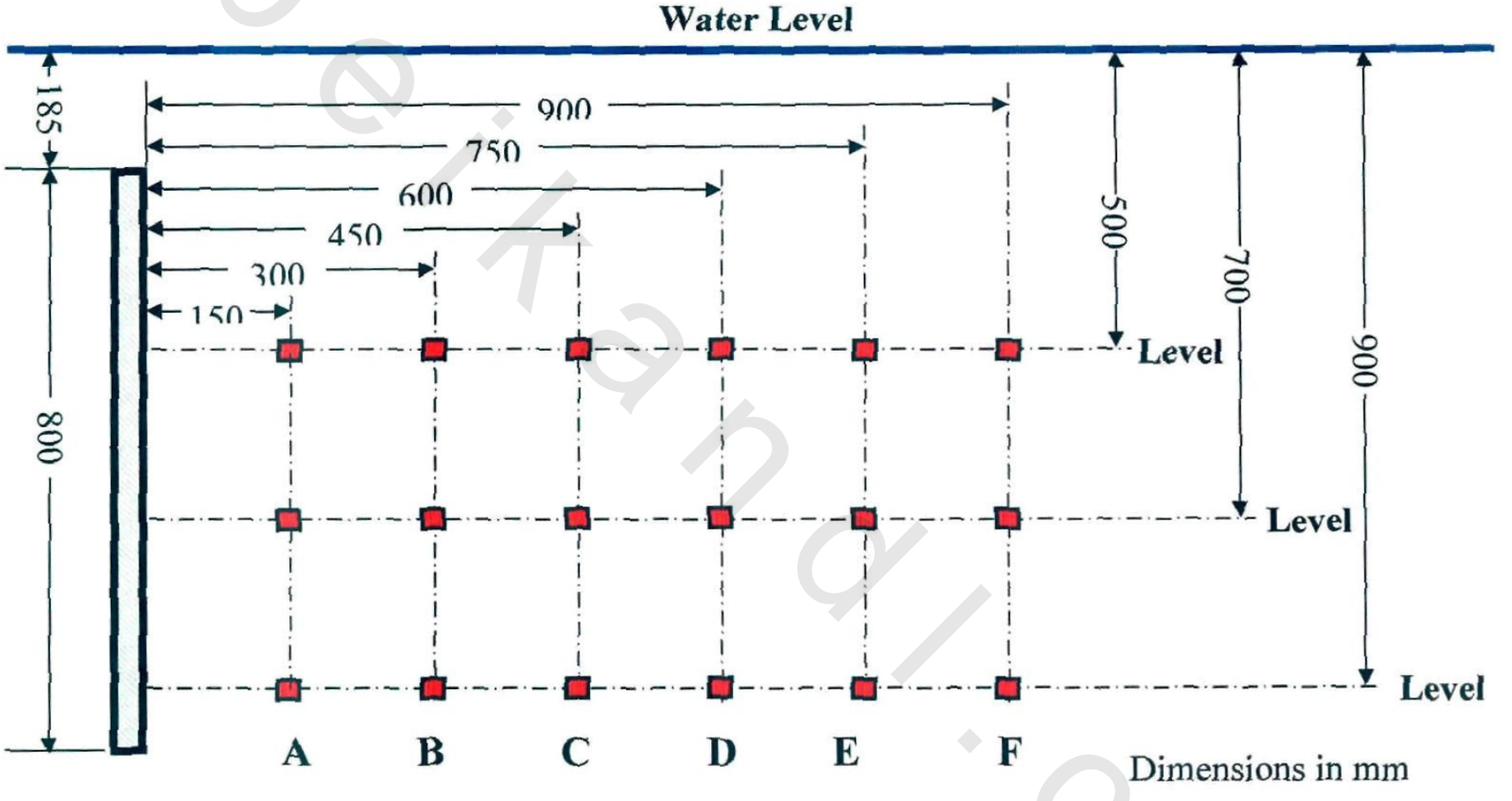


Figure 4.6) Locations of the measuring points at a plane perpendicular to the plate surface at three different planes under the water level and six different points in-line passing through the plate vertical center line

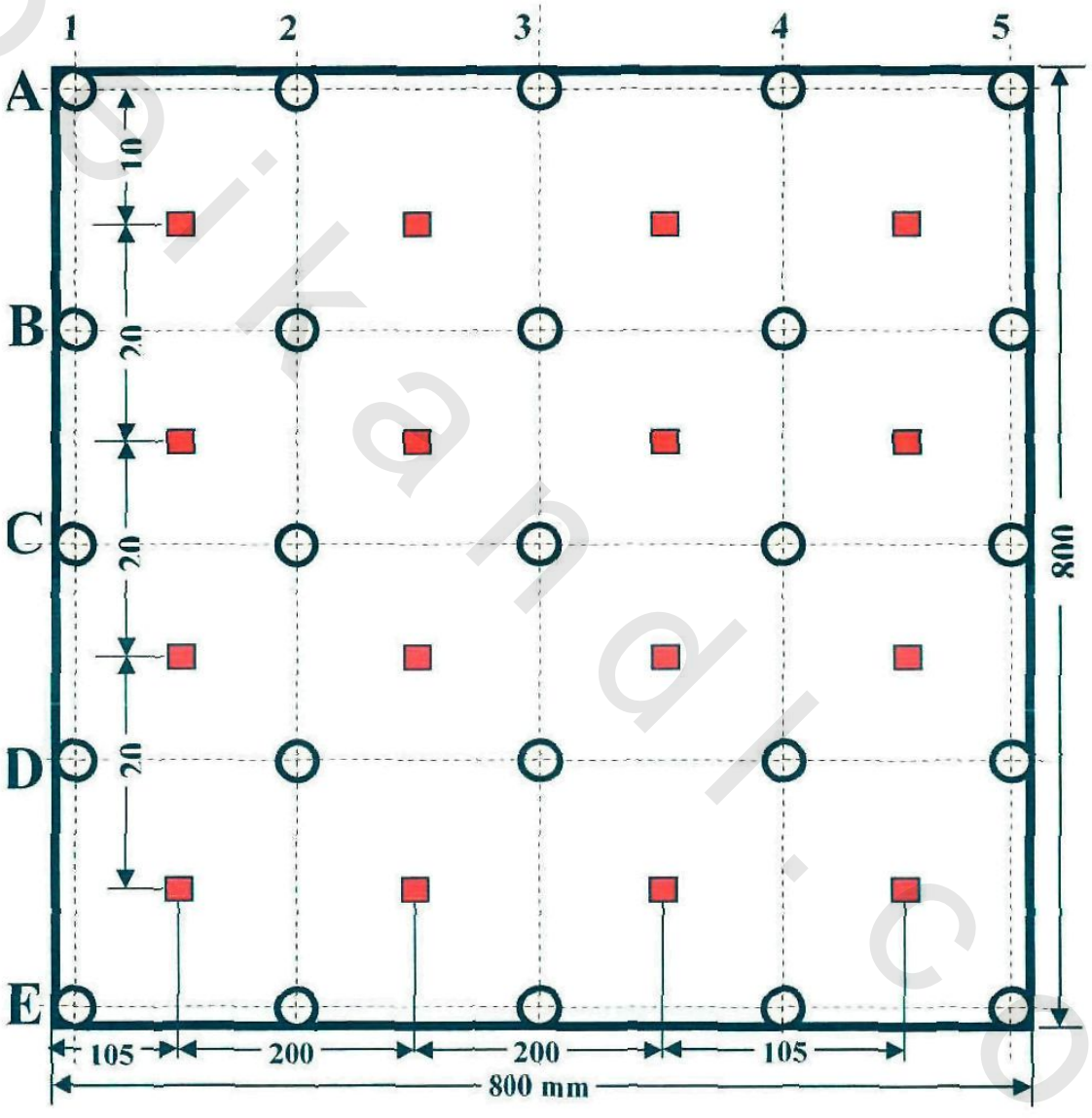


Figure (4.7) Locations of the measuring points parallel to the plate surface pointing to the mid-point between the coupons centers at a plane 25 mm from the plate.