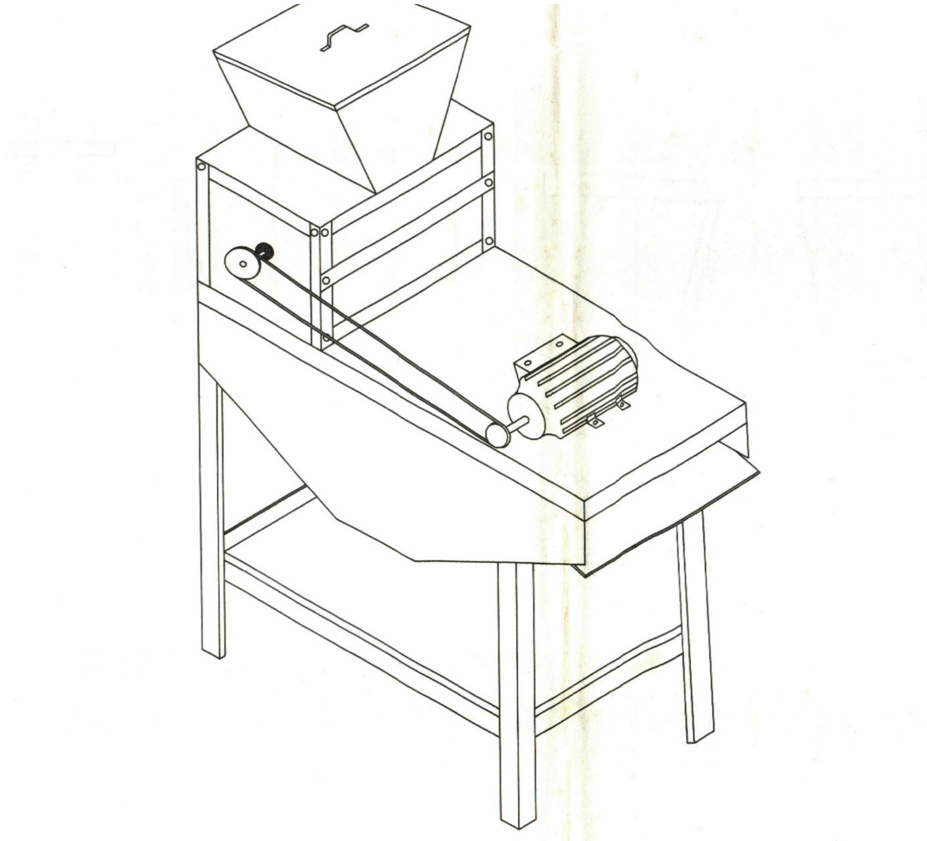

Figure 5: Isometric view of the beans shelling machine

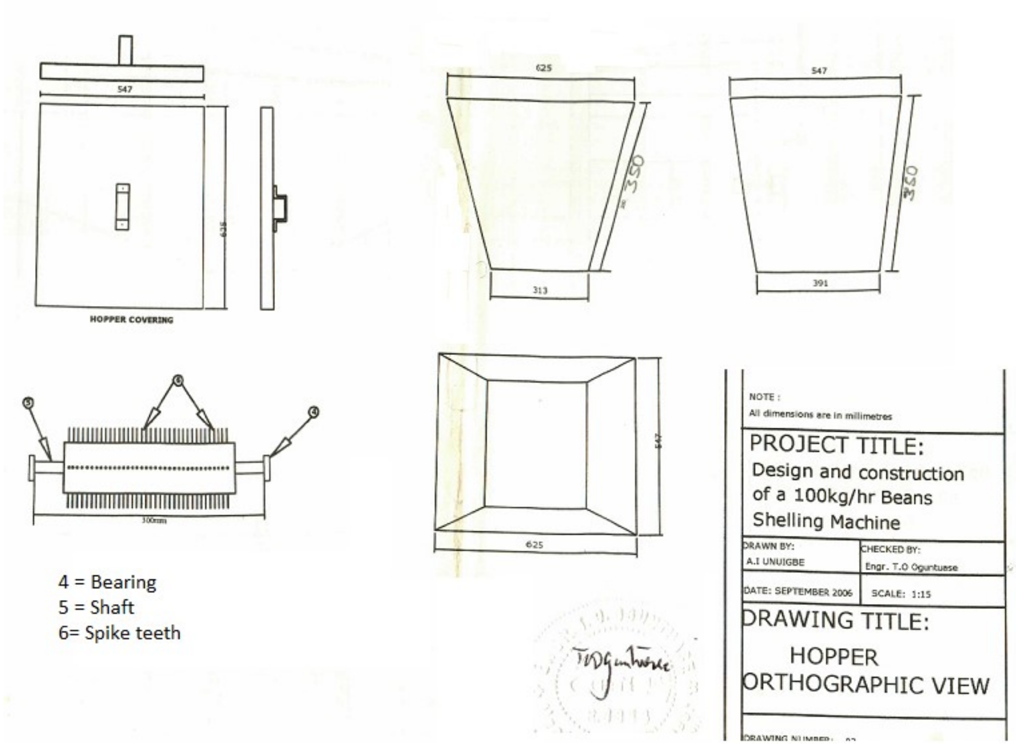

Figure 6: Hopper Orthographic View

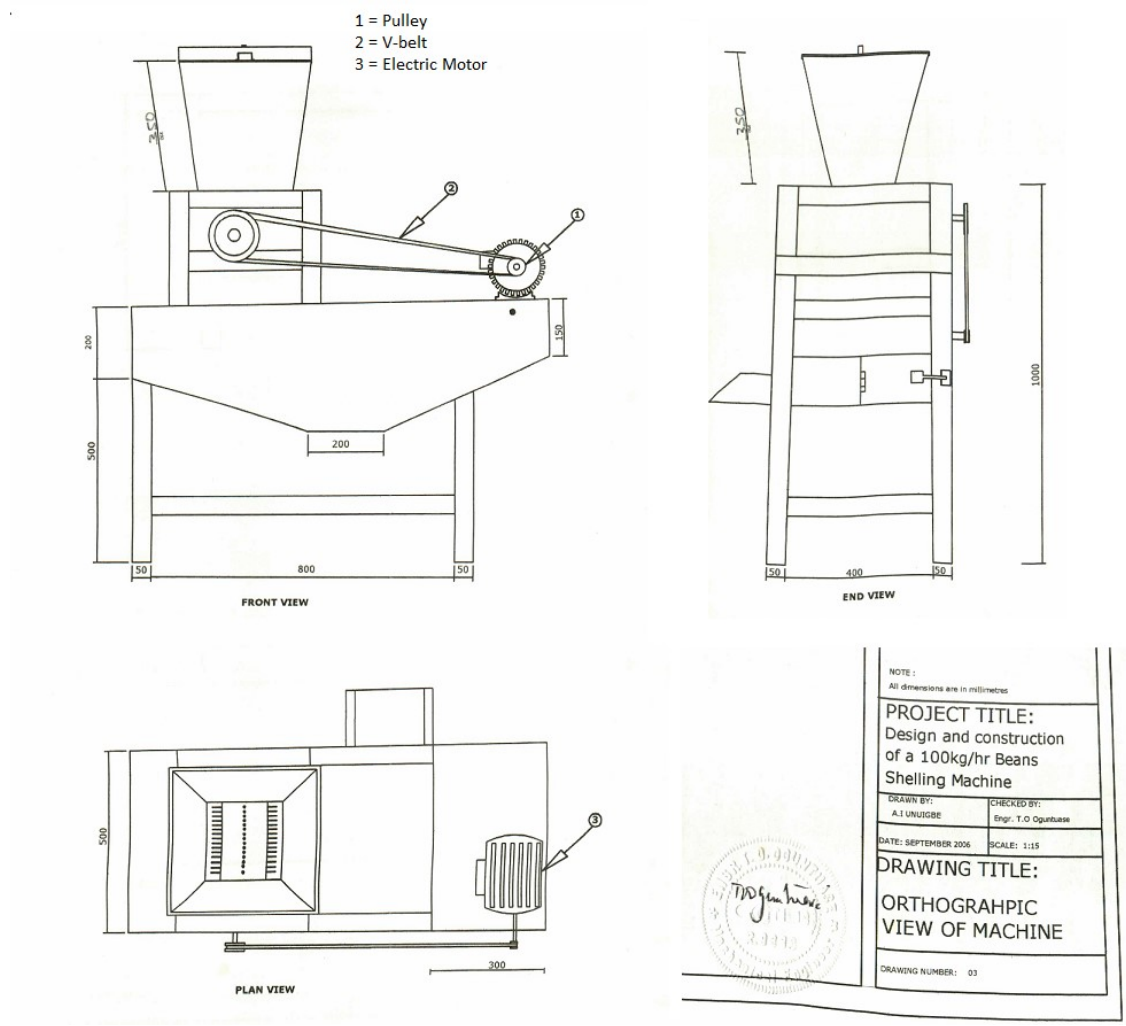

Figure 7: Orthographic view of Machine

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New Technique for Enhancing the Anodes Performance of Cathodic Protection Deep Well Systems

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Abstract:

A special round-grain construction was suggested for use as a grout material surrounding the anode case of deep well groundbed in an impressed current cathodic protection systems. The experimental results show that the proposed grout material is relatively uncrushable to protect the anode groundbed from collapsing of the wells to undermine, having a good electrical conductivity (low resistivity) which increase the active size of anode, provide a lower electrical resistance to surrounding earth and reduce anode consumption resulting from current discharge. The proposed round-grain shape includes a mixture of different percentage weights of Carbon black powder, Portland cement, Graphite and Surfactant material by mixing (1.8) kg of grout powder with (1) liter of water (mixing ratio 1.8:1) which may be pumped between the groundbed steel casing and soil bore well for a substantial distance up from minimal of the well and in the vicinity of the casing and ultimately to the land surface.

Keywords: Cathodic Protection(CP), Grout material, Deep well groundbed, Impressed current

1. Introduction:

Cathodic protection(CP) is a confirmed method of controlling corrosion of inhumed and immersed metallic construction. The exactly, installed, operated and designed CP system can eliminate the areas of the buried structures that corroded by flowing a direct electrical current. The electrodes installed in the electrolyte (soil or water) in the boundary of construction being protected are passes a direct current. By this pattern, when the direct current is duly distributed over the entire object to be protected and of sufficient quantity then the corrosion can be adequately controlled [1].

Two main types of CP systems in this field can be used to block corrosion. The first type of CP system is "galvanic or sacrificial anode system". This type of anode system is depending on the ordinary "potential difference" that occurs between the assistant electrode (anode) which is installed in the electrolyte and object to be preserved. As a consequence of this "potential difference", electrical current flows from the anode through the electrolyte to the structure because a battery effect is generated. The most suitable materials which are currently used for sacrificial anode systems are "magnesium, zinc and aluminum" [2,3]. Galvanic anode systems are often used when the current requirements are relatively low and in low-resistivity environments [4,5]. The second type of CP uses electrodes in attachment with an external rectifier D.C. power supply". This CP technique is named "an impressed current system". This system can be summarized by assembling electrodes "anodes" in the soil and are joined to the positive side of a power supply (rectifier). The negative side of the rectifier is connected to the construction to be protected from corrosion and a D.C. is going to pass through the soil to the construction from the positive side to the anodes. Long life anode materials are usually used for this technique of CP system such as "high silicon chromium cast iron, graphite, and mixed metal oxide coated titanium".

Experience refers that the conditions where sacrificial anode CP is utmost convenient have simple and direct repairs, repairs where the life expectancy is expected to be about 10 years and repairs where balance sheet costs are limited. Furthermore, the important corrosion problems to large buried structures and surface areas was always addressed by impressed current CP, where life expectancy is expected to be more than 25 years [6,7].

The application of employing deep anode groundbeds to stop corrosion and fast deterioration of structures subsurface is very active method of increasing the life of such structures. Under different conditions, corrosion of such metallic structures has been caused by galvanic action because of the creation of anodic and cathodic areas on the metallic structures. It was proved that corrosion occurred at the anodic area of the structure at which area a current flow was established from the metallic structure into the surrounding environment which acted as an electrolytic midst. However, the cathodic areas of the subsurface structures at which the flow of current was directed or collected from the surrounding medium to the metallic structure were found to remain relatively free from corrosive action.

To protect "large storage tank bottoms, pipelines, well casings and different underground structures", deep anode ground bed systems have been used to distribute CP current for a long time. The continues practices and design of groundbed deep anode systems have an important effect on the performance and age of the construction to be protected.

The typically traditional "deep anode groundbed" plans are accomplished by different "individual discrete anodes in a coke backfill" [8].

Designing and evaluating of a node groundbed system can summarized by the following three correlative key performance issues:

1. System resistance: Different factors affecting the ground bed resistance such as "the soil strata resistivity, active area length, coke backfill quality, and anode spending". deep groundbeds are usually designed to output (1 ohm) or less resistance. The resistance of groundbed is usually changes over the working period.
2. Output of Groundbed: As a result of the power available as actual applied voltage and the circuit resistance, an electrical current output supplied "Ohm's law V=IR". With CP operation, as the resistance of the deep well system changes, the current output of electrical circuit will drop unless more voltage is supplied.
3. Life of CP system: Anode groundbeds are designed to have a limitative life but, indeed they have an actual operating life. The calculated value based on quality and amount of anode installed and the time required to spend the available anode according to the design current is typically referred to design life. Poor design, unperfect component failure, inconvenient installation or operating the whole groundbed system beyond the original designed parameters in some cases may cause the actual system life to exceed the "design life" or may be sometimes much less [9].

Many CP deep groundbeds have been founded by the following steps:

(1) Drilling a 0.15- to 0.30-meter diameter borehole to a desirable depth. CP wells usually range from 30 to 150 meter in total depth. Some wells have been drilled to depths of 250 meter.

(2) Installing a string of anodes in the ground hole within a definite interval, usually named as the "anode interval."

(3) The anode interval will have backfilled with an electrically conductive material around the anodes, such as granular carbon material.

(4) A small-diameter vent pipe will have installed which extend from the top of anode interval to ground surface, or above. The aim of installing such vent pipe is to release generated gases

(5) The annulus between the vent pipe and borehole wall will backfilled with a non-conductive fill material to a height above the anode interval. The backfill material usually consists of a granular small-diameter gravel. The purpose of gravel is to provide a permeable medium for escaping of resulting gases and to stabilize the walls of the borehole.

(6) The annulus between venting pipe and the borehole will have sealed, from the top of the gravel material r fill to land surface, with sealing material.

(7) The well is covered by installing a permanent compact cover over at ground surface.

(8) The anode leads will Connected to a facility to be protected, possibly to a current source(rectifier).

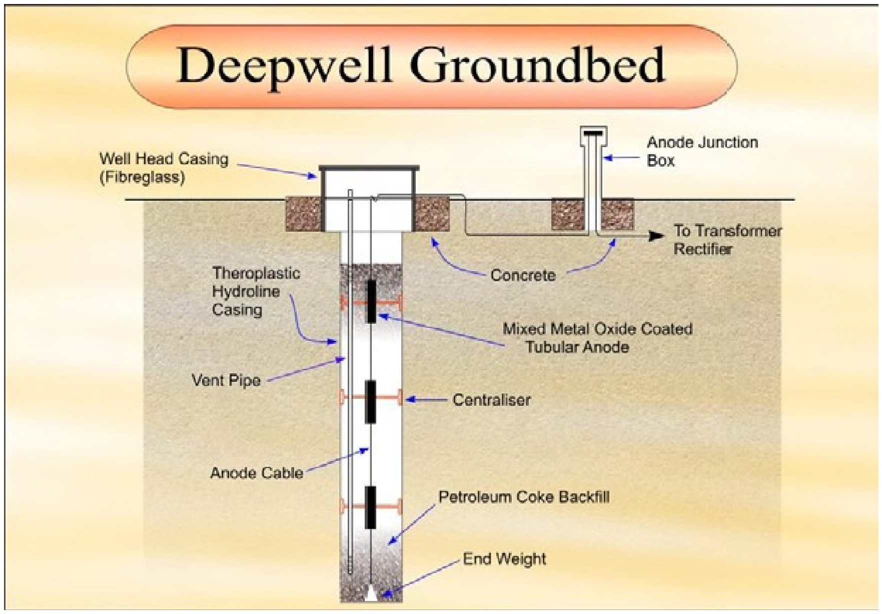


Fig. (1): Schematic diagram of general deep well groundbed CP system [7].

Impressed current installed anodes are surrounded by carbons backfill, kinds of materials use include "coke powder, calcined petroleum coke and natural graphite". The actual purpose of the backfill material is to reduce the CP system resistance by enhancing the effective size of the anode and to insure a medium on which oxidation could occur. This function will prolong anode life. To provide a good electrical contact, the backfill usually packed around the anode. Resistivity of used carbonaceous material is not exceed 0.5 Ω.m and is convenient for use in high resistivity soils. The aim of the backfill materials are to absorb any water and to expand, thus lowering groundbed resistance by providing good contact between anode and soil [10].

CP wells, with any types of wells, can cause natural ground water quality degradation to occur, destroyed CP wells or improperly constructed can cause a preferential pathway for the passage of "poor-quality water, pollutants, and contaminants". CP wells constructed with gravel backfill to land surface are usually permeable to the movement of such poor water and contaminants. Inactive CP wells are a challenge to ground water quality because they become destroyed with time, maybe forgotten, and are sometimes used for different waste disposal.

Soil layers also affect "individual anode output" depending on their electrical properties. The groundbed which passing current that be distributed outward based in large portion on the soil resistivity side view surrounding the coke column, namely the current will flow less easily into higher resistivity regions and more readily into low resistivity regions. For a precisely designed coke column, a low resistance passage is happening not alone from up and down the backfill column but also a low resistance passage from the anode to the backfill column to the soil interface, it is required in higher resistivity soils for the flow from anodes to be able to discharge current in low resistivity soils and transfer up or down the column. In a high conductivity "coke column", the individual anode always give the same outputs in spite of the properties of adjacent soil strata at that anode's elevation.

Different designs, in recent years, have been attempted with deep groundbed wells by a simplest huge steel pipe shell prolonged from beginning of CP system to about 55 - 70 meter down. A source of electrical energy was supplied to the pipe while the upper end of steel pipe was coated to prohibit the electrical current to discharge. Lower end of steel pipe would play as a faraway groundbed to which the power was supplied in order to achieve the flow out of the current to surrounded environment from the CP system to the protected buried object. For such design of construction, age of deep well is subject to electrical current discharged from protection bed and total weight of steel pipe used, likewise the kind of earth in which the bed is existed. Conventionally, after (6 - 9) years of pipe column operation, a detaching at different positions were happen due to the "localized corrosion". When the primary steel pipe, had wearied out and sectionalized and it couldn't have discharged the design current, the primary pipe might replace by another pipe column which placed inside and jointed to system rectifier. Since adjacent soil strata was scattered with a very low resistivity layers which caused to focus the current being discharged and the steel case go to detached in front of consuming the extent of the steel pipe, so this design of foundation is not valid.

The literature shows that studies employ "a full-length pipe with the inside of the pipe being filled with graphite or high silicon cast iron anodes and a carbonaceous backfill". For such kind of CP deep well technique, the steel pipe of bed column over the beginning age of the composition discharged current and was consumed whilst bed anodes stayed basically recumbent. When the steel bed be "sectionalized" and ineffectual, the "anodes and backfill" were intentional to maintain the groundbed system in working. The experiment for such design of structure shows that, as the pipe column stays intact, the resistance of anodes remains always stable. A phenomenon of increasing groundbed resistance will appear when anodes started to take over and the steel pipe material will have exhausted and its body "began to separate", because resistivity through the "backfill" isn't lower than that passing to genuine groundbed pipe. In this case, the flow density of current provided by the rectifier must be increased.

Some designs of CP groundbeds are applied by "anodes and carbonaceous backfill" put together inside deep well groundbeds without using "a full-length steel pipe". The anodes in such design become not practicable and should be changed each few years because the inside walls of holes are break down and therefore another hole had to be drilled since the "anodes" could not be readily changed [11].

The present study suggests a special round-grain conductive construction to protect the deep well ground bed CP system, from collapsing of the walls, by a special grout material molded between the groundbed steel casing and soil bore well for an intrinsic stretch up from the bottom of the well and in the vicinity of casing ultimately to the land surface. This construction with its good electrical conductivity can protect the anode ground bed to undermine, increase the active size of anode, provide a lower electrical resistance to surrounding earth and reduce anode consumption resulting from current discharge.

2. Experimental Work:

By mixing carbon black powder, graphite, Portland cement and a surfactant agent to prepare the grout material suggested in this study to use on the outside of the anode casing **12** with reference to Figure (2). The mineral submerged construction **10** that desired to protect from any "corrosion" to raise the operating age for this construction. A deep well **11** to any required depth is formed by drilling, to minimize or prevent corrosion on the structure **10**. A casing **12** is descend into the deep well. The length of "casing" **12** is designed to stabilize on ground bed depth, and conclude a bit over the ground surface. A tubular steel base portion **13** with upper end being opened. The grout material **17** of this process was prepared by mixing (1.8) kg different percentage weights of above components as shown in table (1) below. The mixture of solids is mixed with water using grout material to water ratio 1.8:1, and introduced into the space between the casing **12** and the bore hole **11**. The injection of the slurry of the grout material continues until reaches the upper level above the position of the anodes **14**. The anodes will have positioned inside the casing **12** until the anodes attains a predetermined location over base portion **13** of the "casing". The desired amount of "carbonaceous material" **15** is inserted into the "casing" to around the anodes to at least above uppermost of the anodes. Gravel **16** is preferably positioned above the space between the casing **12** and well hole **11** and over the grout material **17** situated therein. The "bore hole" **11** receives a casing having a lower portion **13** of steel and an upper portion **18** which is of an inert non-conductive plastic material. A cowl **19** located at upper terminal of the casing **12**, this cowl contains a "vent " **20** and an "electrical conduit inlet" **21**.

2.1 Preparation of grout mold:

Three different grout powder samples were prepared by mixing different percentage weights of Carbon black, Portland cement, Graphite and Surfactant material (nonionic surfactant such as polyethylene oxide) as shown in table (1) below. The proposed grout mold was prepared by mixing (1.8) kg of grout powder with (1) liter of water (mixing ratio 1.8:1) grout powder to water.

Table (1): Composition of the grout powder in different samples.

Sample No.	Carbon black powder wt.%	Portland cement wt.%	Graphite wt.%	Surfactant wt.%
1	80	18	1.5	0.5
2	65	33	1.5	0.5
3	50	48	1.5	0.5

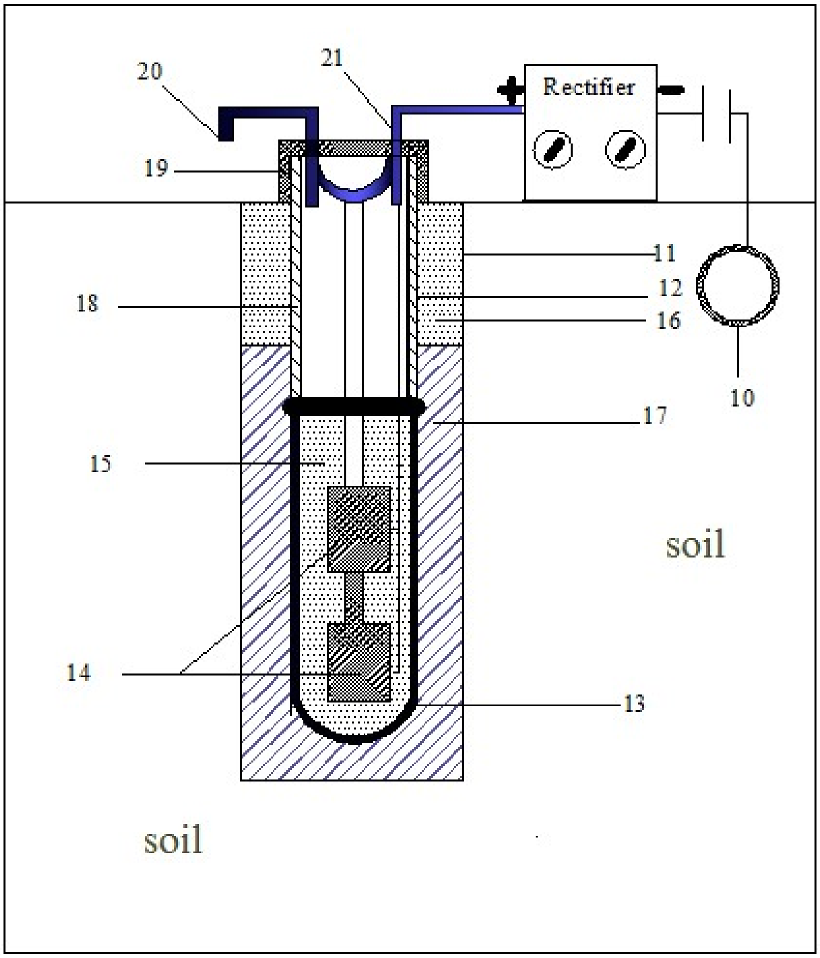


Figure (2): Schematic diagram of Deep Well Groundbed with Proposed Grout material

2.2 Electrical Resistivity and Compressive strength of grout mold:

The electrical resistivity of prepared grout mold samples is measured according to (ASTM C1760 (2012)). A standard sample was molded "(ϕ3.75-in × 2-in)", in which charge was passed through, to record resistance (R) of the prepared samples. The electrical resistivity(ρ) of samples are calculated from the following:

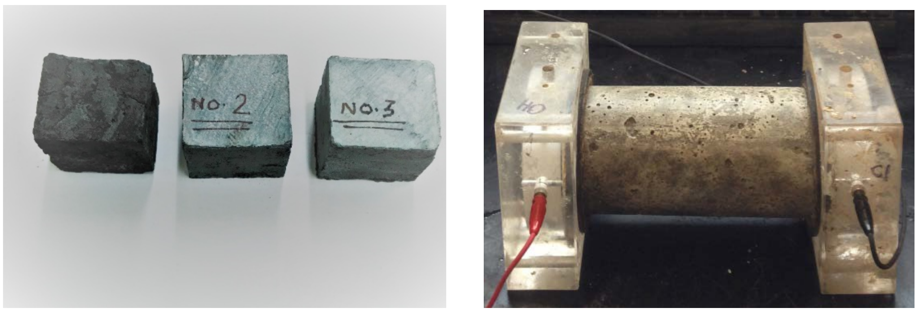
$$R = \frac{V}{I} \quad , \quad \rho = R\,\frac{A}{l}$$

Where; ρ = sample resistivity (Ω·m), R = sample resistance (Ω), V = Applied potential (Volts)
I = measured current (Amps.), A = cross-sectional area (m^2), l = sample length (m)

The compressive strength of prepared samples was measured according to BSEN 12390-3 on 100mm grout cubes [12]. The results were shown in table (2) below:

Table (2): Measured Electrical Resistivity and Compressive Strength.

Sample No.	Electrical Resistivity (Ω·m)	Compressive Strength (MPascale)	Mass Density (kg/m^3)
1	0.111	3.71	1090.2
2	0.322	5.33	1386.4
3	0.954	7.21	1462.0



(a) **(b)**

Figure (2): (a) Cube Samples 100mm for Compressive Strength Test, (b)Resistivity measurement.

3. Discussion of Results:

3.1 Grout mold Composition and Properties:

In order to increase in the ease of mixing, pumping, as well as the increase of density of mold material proposed to use in this study, carbon lubricants (natural graphite) was mixed with carbon black dust to provide a pump lubricant and to enhance the slippage factor of the mold although the graphite partly fills the gaps and cavities between the blended particles and increases intensity of the mixture. For the reason of further increase the readiness and economy of pumping prepared material in a fluidized state a surfactant is blended with different mixtures works as a wetting factor so that when a small amount of liquid such as water is added, the consequent grout mold material is found to be more easily pumped than was a mixture consisting just of the carbon and graphite. The results show that values of grout mold compressive strength are below the normal level for samples (1) and (2), since the composition of the mold does not content any sand or gravel, but it is a reasonably advantageous for use between the "bore hole and the system casing", since there are small lateral stress exerted by the soil strata adjacent to round-grain uncrushable grout shape. The grout shape is considered to be a good buffer for any leakage of natural ground water in vicinity (environment) of the well which causes detrition and wearing out of the steel pipe of groundbed. Since the natural ground water under the bore hole may form " bubbles of hydrogen, oxygen or other gases" due to the large current densities flowing through such water. If allowed to contact the bottom of "casing", these gases will compose an isolating obstruct, this will cause the resistance to flow of electrical current to increase. Furthermore, the grout material can protect ground water quality degradation to occur due to the incorrectly constructed or destroyed CP wells which can appoint a suitable pathway for the entrance of bad-quality surface water, strange materials, and contaminants because they become ruined with time, are occasionally ignored, and are occasionally used for waste disposal.

3.2 Electrical Resistivity of Grout material:

The naturally round and generally unruffled surface of the grout material permits an intensive intimate contact between soil strata and groundbed system. Since each groundbed is designed to protect the buried structure for a distance of more than 15 kilometers, it is required that soil strata in the vicinity (environment) of "bore hole" have a low electrical resistivity. Values of electrical resistivity of proposed material shown in table (2) insures low resistance that causes in most of the electrolytic discharge to occur along the periphery of groundbed anode system and supplying electrical energy so that electrical energy passes readily to the underground constructions from the anode through the conductive grout material and the earth.

Results for electrical resistivity for the prepared grout samples are considered to be a very suitable compared with electrical resistivities of the different soil strata available in the environment of groundbed anode system as shown in table (3) below [13]:

Table (3): Average resistivities of some soils:

Environment	Resistivity, (Ohm.m)
Brackish river water	0.01
Sea water	0.25
Town supply water	10-12
Alluvial soils	10-20
Clays	10-50
Gravel	100-250
Sand	250-500
Sandstone, Dolomite, Granite, igneous and metamorphic rock	1000-10000

The grout material suggested in this work is considered to be a very suitable protecting buffer since the corrosiveness of an environment soil, have a direct effect on ground bed steel casing, which can be classified due to its resistivity as shown in table (4) below and from BS 7361: Part 1[14].

Table (4): Classification of corrosiveness of an environment around Groundbed CP.

Resistivity, (Ohm.m)	Corrosivity Ranking
Up to 10	Severely Corrosive
10 to 50	Corrosive
50 to 100	Moderately Corrosive
100 and above	Slightly Corrosive

4. Conclusions:

The present work is embodied in a low resistance grout material surrounded the groundbed anodes CP system and introduced in the annulus between bore hole and groundbed CP system. The Proposed grout mold material can offer the following properties:

1. Good buffer for any leakage of "ground water" in the vicinity (environment) of the well which causes detrition of steel pipe of groundbed and prevent the collapsing of bore hole. Also, protect ground water quality degradation to occur due to the incorrectly constructed or destroyed CP wells which can appoint a suitable pathway for the entrance of bad-quality surface water, strange materials, and contaminants.

2. The values of electrical resistivity of proposed material insures low resistance so that electrical energy passes readily to the underground constructions from the anode through the conductive grout material and the earth.

3. Increase active size of anode, reduce anode consumption resulting from current discharge and prevent the formation of high resistance to the flow of current due to the formation of "bubbles of hydrogen, oxygen or other gases" on the minimal surfaces of the steel casing.

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