Marconite

MARCONITE® Electrically Conductive Aggregate
An Innovative Earthing Technology

1. INTRODUCTION

In the past, engineers relied on technology, related to generally available minerals, to design the earthing systems for various applications like power stations, buildings, railways, industrial complexes, water & gas plants etc. These earthing systems required presence of water to maintain.

In the late 19th century Marconite® was specifically developed to meet the requirement of all type of earthing applications but without the need of water it. It is electrically conductive black granular, used as backfill material to enhance the effectiveness of the earth to achieve durable, stable and low resistance performing earthing solutions for all types of soil and difficult ground conditions.

Marconite® conducts electricity much the same way as metals, through the movement of electrons. It does not require water to conduct electricity and is not affected by dryness like other ionic based earthing materials such as Bentonite, Charcoal etc. which always require the presence of an effective electrolyte else they dry out and do not conduct electricity.

Marconite® conductive concrete is one of the most suitable materials for treatment of soil. Electrical engineers have been using it to tackle the toughest soil conditions so as to achieve satisfactory earthing solutions throughout the World for over 50 years.

2. SALIENT FEATURES

2.1 Specifications:

a)	Fixed Carbon	98.5 %
b)	Ash, Volatile and Water	1.5 %
c)	Sulphur Content	1.5 % Maximum
d)	Size Grading	10% below 0.10mm 5% above 3.15 mm 85% between 0.10 mm and 3.15 mm
e)	Thermal Stability	Between – 10% and + 60% ambient temperature

2.2 Ultra Low Resistivity: The resistivity of Marconite® is 0.001 Ω-m and when mixed with Portland cement it is still 0.040 Ω-m, which is significantly lower than other earthing materials:-

a)	Marconite® Aggregate	=	0.001 Ω-m
b)	Normal Aggregate	=	30 to 90 Ω-m
c)	Marconite® conducting concrete (Mix with Cement)	=	0.040 Ω-m
d)	Bentonite	=	3 Ω-m upwards

2.3 Versatile: Marconite® is suitable for all types of soil/ground conditions. It becomes a permanent solid structure and does not shrink or gets washed away. It does not require moisture at all. It performs very well in dry soil and hottest climatic conditions.

2.4 Consistent Performance: Once installed, Marconite® based earthing system gives consistent performance and earth resistance value remains the same year after year or shows very insignificant variations.

2.5 Contact area: Solid structure provides larger surface area for dissipation, thus dissipates current faster.

2.6 Chemically Inert: It's pH value is within the neutral range.

2.7 Non-corrosive: Marconite® does not corrode steel or copper conductor or attacks cement structures. It may be noted:-

a) That effect of DC current spreads to a radius of 30 to 50 kms from the earth electrode stations when DC current back flows (Transformer Saturation) or earth return is used to transmit the power in HVDC, which accelerates the corrosion of Earth Electrodes, pipe lines and other metallic objects within it's vicinity.

b) That GIS equipment uses earthed metal screens / enclosures around individual phase conductors and residual AC current flows continuously via earthing system. This causes additional corrosion of earth conductor.

Marconite® encapsulated electrodes are the best solution to protect such corrosion.

2.8 Life: Marconite® based earthing systems has a life of more than 50 years.

2.9 Maintenance: Absolutely maintenance free and does not need water for life. No need to remove, replace or recharge it in order to maintain the desired earth resistance value.

2.10 Environment friendly: Marconite® does not leach and pollute ground water channels like other earthing systems. Use of Marconite® also saves trees from burning to get charcoal.

2.11 No environmental hazard: Marconite® does not pose any environmental hazard for future generations even after the completion of it's life as it disintegrates with soil like any other concrete structure.

2.12 Cost effective: Especially in high resistivity soils, sandy or water logged areas.

2.13 Lowest ownership cost: Long and maintenance free life of Marconite® based earthing Systems makes it's cost lowest among all other earthing systems.

2.14 Easy to Install: Requires only a bore hole or trench to install.

2.15 No space constraint: Gas insulated substation (GIS) occupies only 15 - 25% of the area occupied by the equivalent AIS. Hence it becomes difficult to achieve the required level of Earth resistance in small areas. Marconite® encapsulated deep driven rods are the best solution to achieve low value of ground resistance in such cases.

2.16 Improvement Factor: In practice, improvement of 40% - 60% is generally obtained with the use of Marconite® conductive concrete. Refer Para 13 of this document for case studies.

2.17 Compressive Strength: Marconite® concrete, once it is set, displays a greater compressive strength than Gr 25 concrete & becomes significantly greater over a period of time.

2.18 Metal conductor saving: In designing an earth grid, Dia of conductor is designed oversized to withstand corrosion. Marconite® encapsulated rods solve this problem and also save steel conductor on two counts:-

a) Provision of over designing of conductor is not required in the absence of corrosion.

b) Increased surface area of Marconite® embedded rods reduces the overall requirement of grid's horizontal conductor, which otherwise would be required if bare rods are used.

3. TECHNICAL REFERENCES

Many standards, technical books & papers and web sites have reference of Marconite® conductive concrete/ concrete-encased electrodes. Few of them are mentioned below:-

3.1 IS: 3043 (1st Rev Draft) Cl 9.2.5 for electrode encased in low resistivity material, e.g. Conducting concrete page 71-73. (Under revision by BIS)

3.2 BS: 7430: 2011 Cl 9.5.7 for electrode encased in low resistivity material, e.g. Conducting Concrete page 74-76.

3.3 IEEE Std 80 -2000 Clause 14.6 for concrete encased electrodes page 68.

3.4 Engineers Hand Book on Sub Station Engineering design, Concepts and Computer Applications by R S Dahiya, Kartson books - *page 180.*

3.5 Mc Graw Hill Material's handbook by George S. Brandy, Henery R. Clauser & J A. Vaccaril – page *265.*

3.6 Achieving an acceptable Ground in poor soil-Paper by Keith Switzer, ERICO, Inc.

3.7 WALLIS Soil Survey Report of Royal Offices, Oman recommending the use of Electrically Conductive aggregate Marconite®.

4. TESTS/REPORTS

Marconite® conductive concrete and it's electrodes were tested at various independent National and International laboratories besides testing of material resistivity of each batch is carried out by the manufacturer i.e. M/s Carbon International Limited, UK and test report is provided with all the consignments. Results of tests are appended below:-

4.1 Resistivity - Aggregate:

Results: "Ultra low resistivity of 0.001 Ohm-m."

4.2 Resistivity - Concrete: Marconite concrete (2 Parts Marconite + 1 Part Cement) was tested by one of the overseas laboratory i.e. Fugro Middle East, Dubai for their client M/s Trade Circle Ltd., and material was used for world famous building in Dubai i.e. Palm Jumeirah.

Results: "Ultra low resistivity of 0.040 Ohm-m at 20° C degree."

4.3 Short Current - Electrode: The test was carried out by Central Power Research Institute, Bangalore on two specimens of different sizes of Marconite concrete earth electrodes:-

Results:

Specimens	Current (kA) Peak	RMS	Duration (s)	Ambient temp Temp. ° C
a) Cu rod *L* 3 m, *D* 16 mm, Marconite ® Encapsulation *L* 2.9 m, *D* 75 mm	*39.66*	*22.69*	*1.10*	*29*
b) MS rod *L* 3 m, *D* 40 mm, Marconite ® Encapsulation *L* 2.9 m, *D* 100 mm	*80.52*	*40.13*	*1.11*	*29*

4.4 Earth Resistance - Electrode: Central Power Research Institute, Bangalore measured performance of two specimens of Marconite concrete earth electrodes after 38 days of installation with soil resistivity of 468.29 Ω-m of trial ground:-

Results:

Specimens	*Value Achieved*
a) Cu rod *L* 3 m, *D* 16 mm , Marconite® encapsulation *L* 3 m, *D* 100 mm	= 90.87 Ω

b) MS rod *L* 3 m, *D* 40 mm ,
Marconite® encapsulation *L* 3 m, *D* 200 mm = 55.43 Ω

4.5 Compressive Strength - Cube: Two specimens of 200mm³ cubes were tested by Central Midland Laboratories Birmingham, UK for compressive strength after 7 and 28 days: -

Results:

	After 7 Days	After 28 Days
c) Specimen no 1	22.0 N/mm²	27.5 N/mm²
d) Specimen no 2	23.1 N/mm²	29.5 N/mm²

Conclusion: "It produced a low resistivity and highly conductive material in its Hardened State"

4.6 Chemical Test – ROH's: Marconite aggregate was tested by Muscot Laboratory Service, Bangalore, (DGQA, Ministry of Defense, GOI approved) for various chemicals:-

Results:

Name of Test	Value Ω
a) Lead (Pb)	<0.10 ppm
b) Mercury (Hg)	<0.001 ppm
c) Cadmium (Cd)	<0.1 ppm
d) Nickel (Ni)	<0.1 ppm
e) Arsenic (As)	<0.1 ppm
f) Cyanide (CN)	<0.1 ppm
g) Hexavlent Chromium (Cr^{+6})	<0.1 ppm

Conclusion: *"On the basis of the observed values of the tested marconite earthing material is non hazardous, non polluting"*

4.7 CBIP Technical Report no 78 1991 : Evaluation of Concrete Encased Electrodes & Use of Structural Steel for Earthing, Dept. of Elect. Engineering, Punjab Engineering College, Chd.

a) Passage of AC current steel electrodes embedded in concrete causes only negligible corrosion.
b) Normal stray AC current do not cause deterioration in the strength of concrete.
c) Short duration large currents (like Lightning surges) have negligible effect on the bond between steel and concrete.

Conclusion: Natural steel under such conditions may be safely used as grounding electrode.

5. PRACTICAL ASPECTS OF USING MARCONITE®

5.1 Methodology: Marconite® conductive aggregate is mixed with cement normally in the ratio of 3:1 [3 Parts Marconite: 1 Part Cement] and add one liter of water per kg of total mix to form a fairly dry mix. Normally a bore hole of up to 100 mm Dia may be used. But if required deeper bore holes may be made rather than increasing the Dia of bore hole because surface area benefits obtained with larger diameters are usually negated by the added costs of drilling larger Dia bore holes and increased quantity of Marconite®.

5.2 Single Electrode: Marconite® concrete is poured around the metal conductor in the augured borehole and left it to set into a permanent solid structure.

5.3 Earth Grid: Horizontal conductor of the grid is embedded in Marconite® concrete for larger surface area. It saves over sizing of steel rods, which is used to counter the effect of corrosion in bare rod designs.

5.4 Earth Grid Joints: Cross, parallel and riser's joints of earth grid conductor are embedded in Marconite® conductive concrete to prevent the opening of welded joints due to corrosion. This keeps connectivity of the grid intact for it's life.

6. EARTHING SYSTEM FOR DIFFERENT CONFIGURATIONS

6.1 Electrodes or Earth matt: Once the soil resistivity has been determined then effective earthing system can be designed to meet the earth resistance requirement by using IEEE 80: 2000 Standard - Safety in ac sub-station grounding or such other standards. Any particular earthing system can be: -

a) A single or array of electrodes
a) An extensive ground grid system or earth mat

Earthing electrodes are often installed in straight lines, but it is not always essential. In case the space is limited, then a zigzag system can also be installed by ensuring necessary distance between the electrodes.

6.2 T Piece system: This system combines a borehole of appropriate size with a horizontal trench. It can be used in areas with limited space and is useful in low resistivity soils. There is also an option for connecting T piece systems together to achieve the required earth resistance value. If necessary, a combination of bore holes and T pieces systems can also be used to further reduce the earth resistance. This system is used at a minimum depth of 1 meter to minimize the effects of frost.

7. COMPARISION OF MARCONITE® BASED SYSTEMS WITH TRADITIONAL SYSTEMS

Parameters		Marconite® conductive concrete based systems	Traditional GI pipe / Plate Earthing with Charcoal and Salt	Pipe in pipe/strip systems with back fill Compounds
Technical				
1	Technology	Natural grey Electrically Conductive Concrete.	CI, GI, Cu plate, GI Pipe, Charcoal and Salt.	Pipe in pipe/strip with back fill materials.
2	Design Consistency	Consistency in design.	Coal & Salt vary place to place.	Backfill materials vary.
3	Resistivity of material.	Ultra low resistivity - 0.001 Ω-m.	Resistivity of Charcoal 2.6 X 10-4Ω-m & salt consist 15% - 20% impurities.	Resistivity of back fill materials is 3 -5 Ω-m.
4	Material's ph	Inert	Acidic	Acidic
5	Process	Electronic	Ionic	Ionic
6	Suitability of Electrode	Good for Granite, Hilly terrains, Sandy soil, Made up ground, Water Logged Areas, River beds, Sea shores & Salty soils etc.	Difficult to install in Granite, Rocks, Hilly terrains, Water Logged Areas, River beds & Sea shores etc.	Difficult to install in Granite, Rocks, Hilly terrains, Water Logged Areas, River beds & Sea shores etc.
7	Easy Installation	Only a borehole is required. In rocky soils it works in low depth tranches also.	Wider excavation is difficult in rocky soils. Thus high cost of installation.	Digging is difficult in rocky soils. Thus high cost of installation.
8	Life	50+ years	8 years	10 years

9	Performance	Constant Electrical Conductivity Un-affe-cted by Environment Temp. & Moisture. Does not leach or gets washed away in wet soils Performance permanent & consistent.	Watering dissolves salt into soil. Fails to provide safe discharge path or do not activate fault protection due to corrosion. Fluctuations of Ohmic value results in frequent problems.	Back fill material sweeps away in earth water channels which affects performance.
10	Current Dissipation	Impregnated aggregate greatly increases the conductive surface area of electrode & Current dissipation stages.	Has single stage current dissipation.	Surface of pipe has smaller area for dissipation.
11	Maintenance	Lifelong maintenance free and does not require water.	Requires watering & recharge of salt on regular basis.	Requires watering & recharge of back fill material regularly.
12	Corrosion	No Corrosion since metal rod is embedded in inert neutral material.	Corrodes due to moisture and heat, which affects the performance.	Pipe corrodes due to moisture and heat, which affects the performance.
Environmental				
14	Environment friendly	Conductive concrete does not leach or pollute earth water channel. Save trees.	Trees cut for charcoal. Salt dissolves and pollutes the water channel.	Back fill materials leaches into ground and pollutes the water channel.

8. COST COMPARISION : MARCONITE® BASED SYSTEMS WITH TRADITIONAL SYSTEM

		Marconite Electrode ***D*** 100mm, ***L*** 3 m	GI Pipe ***D*** 40 mm, ***L*** 3 m	GI plate ***L*** 0.6 m X ***W*** 0.6 m
1	**Capital Cost**			
a	**On a/c of Surface area** Surface area of one unit [Electrode]	0.958 sq m	0.380 sq m	0.720 sq m
b	Equaling area of other electrodes	1	2.52 times	1.33 times
c	**On a/c of Life Cycle** No of units required - 50 yrs	50 yrs / 50 yrs = 1 Electrode	50 yrs / 8 yrs = 6.25 Electrodes	50 yrs / 10 yrs = 5 Electrodes
d	Total no of units required for a life of 50+ yrs [b*c]	One unit	2.52 X 6.25=15.75 or 16 units	1.33 X 5 = 6.65 or 7 Units
c	Cost of one unit with installation	Rs 16,500/- each	**As CPWD DSR 2014** 4.5 m Rs 3,926/- or 3.0 m Rs 2,618/-	**As CPWD DSR 2014** Rs 4,500/-
f	Electrode's cost of Capital 50 yrs.	Rs 16.500/- X 1 = **Rs 16,500/-**	Rs 2,618/- X 16 = **Rs 41,888/-**	Rs 4,500/- X 7 = **Rs 31,500/-**
2	**Maintenance Cost**			
	Cost of Water, Salt and Labor for one unit.	Water or recharge is not required for life.	- Water yrly 6 times : Rs 10 X 6 = Rs 60/- - Watering labor yrly: Rs 50 X 6= Rs 300/- - Salt yearly with labor Rs 600/- **- Yrly Cost Rs 960/-** - Cost of life for 1 unit Rs 960*7 yrs = Rs 6,720/-	- Water yrly 6 times : Rs 10 X 6 = Rs 60/- - Watering labor yrly: Rs 50 X 6 = Rs 300 - Salt yearly with labor Rs 600/- **-Yrly Cost Rs 960/-** - Cost of life for 1 unit Rs 960*9 yrs = Rs 8,640/-

	Total maintenance Cost for 50 years		Cost of life for 16 units @ Rs 6,720 each *16 = Rs 1,07,520/-	Cost of life for 7 units @ Rs 8,640 each *16 = Rs 86,480/-
3	**Life Cycle Cost**			
	Capital Cost	Rs 16.500/-	Rs 41,888/-	Rs 31,500/-
	Maintenance for 50 years	NIL	Rs 1,07,520/-	Rs 86,480/-
	Total Cost	**Rs 16,500/-**	**Rs 1,49,408/-**	**Rs 1,17,980/-**

9. THEORETICAL CALCULATIONS OF PERFORMANCE OF VARIOUS EARTHING SYSTEMS IN DIFFERENT SOIL RESISTIVITY

Soil Resistivity Ω m	Expected Earth resistance Ω			
	Marconite Embedded	GI / MS Ground Rod	GI Pipe	GI / Cu Plate
	D 100 mm, L 3m	D 16 mm, L 3 m	D 40 mm, L 3 m	0.6. m X 0.6 m
2	0.48	0.67	0.57	0.74
3	0.7	1.00	0.86	1.1
4	1.0	1.34	1.14	1.5
5	1.2	1.67	1.43	1.8
6	1.4	2.01	1.72	2.2
7	1.7	2.34	2.00	2.6
8	1.9	2.68	2.29	3.0
9	2.1	3.01	2.58	3.3
10	2.4	3.35	2.86	3.7
11	2.6	3.68	3.15	4.1
12	2.9	4.02	3.43	4.4
14	3.3	4.69	4.01	5.2
16	3.8	5.36	4.58	5.9
18	4.3	6.03	5.15	6.6
20	4.8	6.70	5.72	7.4
22	5.2	7.37	6.30	8.1
24	5.7	8.04	6.87	8.9
26	6.2	8.70	7.44	9.6
28	6.7	9.37	8.01	10.3
30	7.1	10.04	8.59	11.1
32	7.6	10.71	9.16	11.8
34	8.1	11.38	9.73	12.6
36	8.6	12.05	10.30	13.3
38	9.0	12.72	10.88	14.0
40	9.5	13.39	11.45	14.8
42	10.0	14.06	12.02	15.5
44	10.5	14.73	12.59	16.3
46	10.9	15.40	13.17	17.0
48	11.4	16.07	13.74	17.7
50	11.9	16.74	14.31	18.5
52	12.4	17.41	14.88	19.2
54	12.8	18.08	15.45	19.9
56	13.3	18.75	16.03	20.7
60	14.3	20.09	17.17	22.2
62	14.7	20.76	17.74	22.9
64	15.2	21.43	18.32	23.6
66	15.7	22.10	18.89	24.4
68	16.2	22.77	19.46	25.1
70	16.6	23.44	20.03	25.9
72	17.1	24.11	20.61	26.6
74	17.6	24.77	21.18	27.3
76	18.1	25.44	21.75	28.1
78	18.5	26.11	22.32	28.8
80	19.0	26.78	22.90	29.5
82	19.5	27.45	23.47	30.3
84	20.0	28.12	24.04	31.0
86	20.4	28.79	24.61	31.8
88	20.9	29.46	25.19	32.5

Soil Resistivity Ω m	Expected Earth resistance Ω			
	Marconite Embedded	GI / MS Ground Rod	GI Pipe	GI / Cu Plate
	D 100 mm, L 3m	D 16 mm, L 3 m	D 40 mm, L 3 m	0.6. m X 0.6 m
90	21.4	30.13	25.76	33.2
92	21.9	30.8	26.3	34.0
94	22.3	31.5	26.9	34.7
96	22.8	32.1	27.5	35.5
98	23.3	32.8	28.0	36.2
100	23.8	33.5	28.6	36.9
105	24.9	35.2	30.1	38.8
110	26.1	36.8	31.5	40.6
115	27.3	38.5	32.9	42.5
120	28.5	40.2	34.3	44.3
125	29.7	41.8	35.8	46.2
130	30.9	43.5	37.2	48.0
135	32.1	45.2	38.6	49.9
140	33.3	46.9	40.1	51.7
145	34.5	48.5	41.5	53.6
150	35.6	50.2	42.9	55.4
155	36.8	51.9	44.4	57.2
160	38.0	53.6	45.8	59.1
165	39.2	55.2	47.2	60.9
170	40.4	56.9	48.7	62.8
175	41.6	58.6	50.1	64.6
180	42.8	60.3	51.5	66.5
185	44.0	61.9	52.9	68.3
190	45.1	63.6	54.4	70.2
195	46.3	65.3	55.8	72.0
200	47.5	67.0	57.2	73.9
210	49.9	70.3	60.1	77.6
220	52.3	73.7	63.0	81.3
230	54.7	77.0	65.8	84.9
240	57.0	80.4	68.7	88.6
250	59.4	83.7	71.6	92.3
260	61.8	87.0	74.4	96.0
270	64.2	90.4	77.3	99.7
280	66.5	93.7	80.1	103.4
290	68.9	97.1	83.0	107.1
300	71.3	100.4	85.9	110.8
325	77.2	108.8	93.0	120.0
350	83.2	117.2	100.2	129.3
375	89.1	125.5	107.3	138.5
400	95.0	133.9	114.5	147.7
450	106.9	150.7	128.8	166.2
500	118.8	167.4	143.1	184.7
600	142.6	200.9	171.7	221.6
700	166.3	234.4	200.3	258.5
800	190.1	267.8	229.0	295.5
900	213.8	301.3	257.6	332.4
1000	237.6	334.8	286.2	369.3
1100	261.4	368.3	314.8	406.3

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10. CASE STUDIES

In order to demonstrate the practical benefits of use of Marconite® many studies were carried out to compare Marconite® encapsulated electrodes with other earthing systems, which clearly shows better performance. Few cases are mentioned below:-

Sr No	Customer's Name & Earth Electrode's Specifications	Resistance Achieved of Marconite Electrode	Theoretical Calculations of Resistance of Bare rod	Soil Resistivity of the Location	Improvement in Resistance %
1	**CPRI, Bangalore** Cu rod – D 16 mm, L 3 m Marconite Embedding - D100 mm, L 3 m	90.87 Ω	156.7 Ω	468.3 Ω-m	42.0 %
2	**CPRI, Bangalore** Cu bonded MS rod – D 40 mm, L 3 m Marconite Embedding – D 200 mm, L 3 m	55.43 Ω	130.4 Ω	468.3 Ω-m	57.5 %
3	**NDMC, New Delhi** Cu rod – D 16 mm, L 3 m Marconite Embedding – D 100 mm, L 3 m	0.15 Ω	4.8 Ω	14.5 Ω-m	96.9 %
4	**Indian Air Force, Palam New Delhi** MS rod – D 16 mm, L 30.5 m Marconite Embedding–D100 mm, L 30.5 m	0.76 Ω	1.7 Ω	38.2 Ω-m	55.9 %
5	**Indian Oil Corp. Ltd., Panipat** Cu rod – D 16 mm, L 3 m Marconite Embedding–D100 mm, L 3 m	1.84 Ω	6.5 Ω	19.5 Ω-m	71.8 %
6	**All India Radio, New Delhi** MS rod – D 16 mm, L 4.56 m Marconite Embedding–D100 mm, L 4.5 m	0.76 Ω	2.4 Ω	10.3 Ω-m	69.7 %
7	**Tata Power - DDL, New Delhi** MS rod – D 16 mm, L 3 m Marconite Embedding–D100 mm, L 3 m	0.88 Ω	14.3 Ω	43.9 Ω-m	93.8 %

11. OUR VALUED CUSTOMER

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SUMMARY: This Technical Bulletin documents the significant benefits that can be obtained by designing and using an earthing system based on Marconite® conductive concrete. We believe that Marconite® would provide a cost effective solution to your earthing requirements.

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