Using bottom ash as filling in the burial of underground gas and fuel facilities

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1. Presentation of the problem

   Metal underground facilities used for various purposes (such as gas and fuel containers; as well as underground lines) are backfilled and padded with sand, usually dune sand. The purpose of the padding is to enclose the object in a protective layer so that it is not mechanically struck or jarred during installation, as well as to distribute the mechanical force and load exerted on the underground object by the transportation passing above the site where the metal underground object is buried.

   The backfill must enable horizontal balancing and the distribution of mechanical stress without causing galvanized corrosion of the metal buried in the above backfill. That is why the filling material must meet the most stringent requirements and not cause subterranean corrosion, even if the filling becomes wet as a result of water penetrating the earth in the area of and above the buried facilities.

   Dune sand has been used for a number of years (sea sand, which is salty, must not be used, a demand that is difficult to enforce without stringent testing, because harmless dune sand may be found mere meters away from corrosive salty sand). With the decreasing availability of dune sand, which as stated is the preferred substance for use, we are seeing increasing demand for an alternative substance that can fulfill all the functions currently provided by controlled dune sand.

   One of the most easily available materials is bottom ash, which represents about ten percent of the overall amount of coal ash produced in coal-driven power stations. Bottom ash is produced by the cohesion of relatively heavy mineral particles obtained from the incineration of coal that precipitate in the cooling pool located at the bottom of the boiler. The wet bottom ash is taken from the cooling pools to the storage tanks by means of a conveyor belt, and from there to the intermediate storage piles in the power station yard. The bottom ash is transported for use in trucks covered with a tarpaulin. This ash has the appearance of coarse sand and is dark gray, and the particles do not exceed ten millimeters in size.

   The bottom ash can be classified by size in order to obtain a product with finer particles. In this case, the chances of the bottom-ash filling leaking through the outer industrial layer or being harmed mechanically are very slight.

2. The corrosive aspect

   The question that always arises when the possibility of steel coming in contact with a product originating in “coal” is whether corrosion will not develop due to the filling material.

At the initiative of the National Coal Ash Board, our firm, which has specialized in the prevention of corrosion for the past 40 years, launched a series of experiments over a number of months in order to verify beyond all reasonable doubt that the use of coal ash under normal installation conditions does not cause any danger of corrosion.

In order to examine this critical issue, it is necessary to focus on the reciprocal relations between the filling surrounding the vessel or underground piping and the level of the item's coating. All the vessels used in the world and in Israel are currently coated in an advanced coating, which is tested by authorized parties before use. A mechanical default is always possible, but this is backed up by complementary cathodic protection so that the coating serves only as the first line of the defense against corrosion. In other words, the steel first "sees" the industrial coating, after that the backfill, and only after that, the natural soil present in the surroundings. Consequently, in order for corrosion to appear, the industrial coating would have to first be compromised by the backfill.

Despite this, we must relate to even the most unlikely scenario: What would happen if over time, the backfill is in fact compromised and the facility's steel (the vessel) "sees" the filling?

In corrosion engineering, soil and environments are classified based on the criterion of "resistivity," which is measured in units of ohmcm. This resistivity physically sums up the effects and concentrations of chemicals present in the filling or the filling environment in the nearby soil. A resistivity of a few thousand ohm centimeters (3,000 and up) is not considered dangerous.

In our labs, our firm conducted a large number of tests on bottom ash samples provided to us from various sites. We mixed the samples with distilled water and found no decrease in resistivity from values of 3,000-4,000 ohm centimeters. In international standards, these values are not considered "corrosive."

Another problem remains: Are the piles of coal ash found in the yard of the power station homogeneous in relation to depth, and are there significant disparities in resistivity in relation to the depth of the various piles. We used the Wenner method, which can measure the resistivity of soil surface at varying depths of the pile. Here too, no differences or disparities were found in the different depths of the pile.

Conclusion: Bottom ash as a combustion product is in fact a homogeneous medium.

The test cannot determine if the pile contains stones or hard masses. If we go back to the example of dune sand – there, experience has shown there are no stones or rocks – in our case, it is necessary to sift the ash in order to ascertain that it does not contain large or sharp particles that could pierce the coating, and in order to determine statistically that the danger of injuring the coating is of low probability.

In conclusion, from the aspect of corrosion engineering, there is no impediment to the use of coal ash as a backfill for fuel vessels and underground piping that are already protected by complementary cathodic protection. However, to be on the safe side, it is advisable to periodically ascertain that the combustion conditions in the power station have not changed, and consequently, it is necessary to have constant supervision by a corrosion engineer to carry out random testing and supervise the production process in order to make sure that the basic parameters have not changed.

Appendix 1

Test for resistivity of bottom ash samples randomly collected and measured in a standard soil box using a state-of-the-art Italian-made electronic earth Megger.

- The purpose of the test is to determine if bottom ash contains water-soluble elements that could significantly lower the resistivity of the wet ash, as measured in units of ohm centimeters.
- For the test, we used distilled water, which has practically infinite resistivity, before wetting the ash sample.
- If the resistivity does not change after the addition of varying proportions of distilled water, it means that there are no salts that can be leached from the ash.
- It should be noted that this is one of the most widely accepted criteria for assessing various kinds of soil and environments. Test method AASHTO T 288-91 (1966) determines that the soil or filling must have a resistivity that is not lower than 3,000 Ohm-cm.

A large number of tests were carried out, with almost identical results, mostly greater than 5,000 Ohm-cm.

It should be recalled that this test relates to a specific, but representative sample.

In order to attain average values in the piles, we used the Wenner method for varying depths.

No.	Natural condition before wetting	10%	15%	20%
1	Infinity	5000	4630	4210
2	Infinity	5000	4800	4600
3	5220	5200	5100	4960
4	Infinity	4680	3900	3650
5	5000	4800	4150	3800
6	Infinity	5000	4900	3700
7	Infinity	5000	5000	4900
8	5000	5000	5000	4850
9	6400	5500	5000	4890

The obvious conclusion: Even if the filling becomes wet, no significant increase in electrical conductivity can be expected. Note: conductivity is the reciprocal value of specific resistivity.

Appendix 2

Measurements of resistivity in layers of bottom ash using Wenner method in Hadera power station site

- The measurements were carried out on May 23, 2004.
- The measurements were carried out using a Megger DRT 3/2 measurement tool.
- The interpretation of the results was carried out using Interpex's Resix plus v2 program.

8 Pile 1 (west) Location 1

1.1 Measurement results

Distance between pines (meters)	Resistivity (ohm)	Virtual Resistivity (ohm-m)
0.5	80	25120
1	29.3	18400
1.5	21.6	20347
2	13	16328
3	7.4	13942
4.5	2.9	8195
7	1.77	7781
10	1.03	6468

1.2 Interpretation of results

No.	Spacing (meters)	Data Resistivity (ohm-m)	Synthetic Resistivity (ohm-m)
1	0.500	251.0	250.6
2	1.00	184.0	201.1
3	1.50	203.0	185.1
4	2.00	163.0	166.2
5	3.00	140.0	129.0
6	4.50	82.00	92.45
7	7.00	78.00	71.35
8	10.00	65.00	67.30
		NO DATA ARE MASKED	

Layered Model

L#	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)
1	13198.2	0.0941	- 0.0941
2	205.9	2.17	-2.27
3	16.33	0.539	-2.81
4	68.80		-2.81

2. Pile 1 (west) Location 2

Measurement results

Distance between pines (meters)	Resistivity (ohm)	Virtual Resistivity (ohm-m)
0.5	66.5	20881
1	38.5	24178
1.5	29.7	27977
2	16.3	20473
3	6.4	12058
4.5	5.3	14978
7	2.5	10990
10	1	6280

Interpretation of results

No.	Spacing (meters)	Data Resistivity (ohm-m)	Synthetic Resistivity (ohm-m)
1	0.500	208.0	224.9
2	1.00	242.0	222.5
3	1.50	280.0	216.5
4	2.00	205.0	206.9
5	3.00	121.0	180.9
6	4.50	150.0	139.8
7	7.00	110.0	93.21
8	10.00	63.00	68.72
		NO DATA ARE MASKED	

Layered Model

L#	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)
1	173.1	0.0150	-0.0150
2	225.6	3.09	-3.10
3	45.53	0.214	-3.32
4	51.36		-3.32

3. <u>Pile 2 (east) Location 1</u>

3.1 Measurement results

Distance between pines (meters)	**Resistivity (ohm)**	**Virtual Resistivity (ohm-m)**
0.5	148	46472
1	47	29516
1.5	19.7	18557
2	15.9	19970
3	10.3	19405
4.5	3.76	10626
7	1.55	6814
10	0.8	5024

3.2 Interpretation of results

No.	**Spacing (meters)**	**Data Resistivity (ohm-m)**	**Synthetic Resistivity (ohm-m)**
1	0.500	464.0	468.9
2	1.00	295.0	272.8
3	1.50	186.0	222.5
4	2.00	200.0	199.0
5	3.00	195.0	161.4
6	4.50	106.0	114.3
7	7.00	68.00	69.37
8	10.00	50.00	49.66
9	15	42.00	41.63
		NO DATA ARE MASKED	

Layered Model

L#	**RESISTIVITY (ohm-m)**	**THICKNESS (meters)**	**ELEVATION (meters)**
1	771.7	0.312	0.312
2	213.5	2.68	-2.99
3	38.42		-2.99

4. Pile 2 (east) Location 2

4.1 Measurement results

Distance between pines (meters)	Resistivity (ohm)	Virtual Resistivity (ohm-m)
0.5	89	27946
1	15.7	9860
1.5	6.65	6264
2	6.1	7662
3	6	11304
4.5	3	8478
7	0.86	3781
10	0.49	3077

4.2 Interpretation of results

No.	Spacing (meters)	Data Resistivity (ohm-m)	Synthetic Resistivity (ohm-m)
1	0.500	280.0	278.4
2	1.00	99.00	96.30
3	1.50	63.00	88.61
4	2.00	77.00	85.01
5	3.00	113.0	77.11
6	4.50	85.00	64.43
7	7.00	38.00	48.46
8	10.00	31.00	38.74
9	15.00	41.00	33.08
		NO DATA ARE MASKED	

Layered Model

L#	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)
1	2522.1	0.171	-0.171
2	88.65	3.35	-3.52
3	29.82		-3.52