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High-Density Polyethylene (Hdpe) as a Replacement Material for Carbon Steel Pipes in Geothermal Projects

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ABSTRACT

Traditionally, carbon steel has been the material of choice for fluids flow in geothermal applications. Recent advances have proven that for applications that don't require high temperatures (< 60^{o}C) High-Density Polyethylene (HDPE) is a strong competitor to carbon steel. Its suitability in geothermal environment for low temperature fluids is unmatched. From its corrosion resistance, to its adaptability in seismic zones, ease of laying and lower costs, HDPE is becoming a choice for a variety of applications.

Various projects in the world have used HDPE as a replacement for steel, in areas where safety and reliability is a big concern. In all cases, HDPE has emerged as a worthy competitor. In Callaway Nuclear Power Plant, AmerenUE, a subsidiary of Ameren Corporation, has pioneered the use of polyethylene (PE) as a new alternative to steel pipe ESW systems. If HDPE exceeds the safety expectations of nuclear installations, then it will also surpass requirements for geothermal applications of a similar nature. Wayang Windu geothermal plant in West Java, Indonesia has demonstrated how PE pipes can be used to help reduce the corrosion and extend the operation life of geothermal plants.

This paper will look at the various options available for African countries developing geothermal to benefit from HDPE as a material to substitute steel in areas like fresh water supply, disposal of low temperature geothermal fluids and as a possible candidate for cellar drainage casings. The cost benefit analysis will be carried out, giving out the expected total life cycle costs of the system as compared to steel.

1. Introduction

1.1 Olkaria Geothermal Field

The Olkaria Geothermal Field is a region located immediately to the south of Lake Naivasha in the Eastern Branch of Great Rift Valley of Kenya (Figure 1). It was the first geothermal field to be developed in Africa, and hosts the largest geothermal power plants in the continent. KenGen has an installed capacity of 514MW (June 2016). The potential of the field has been estimated to be about 1,200MW.

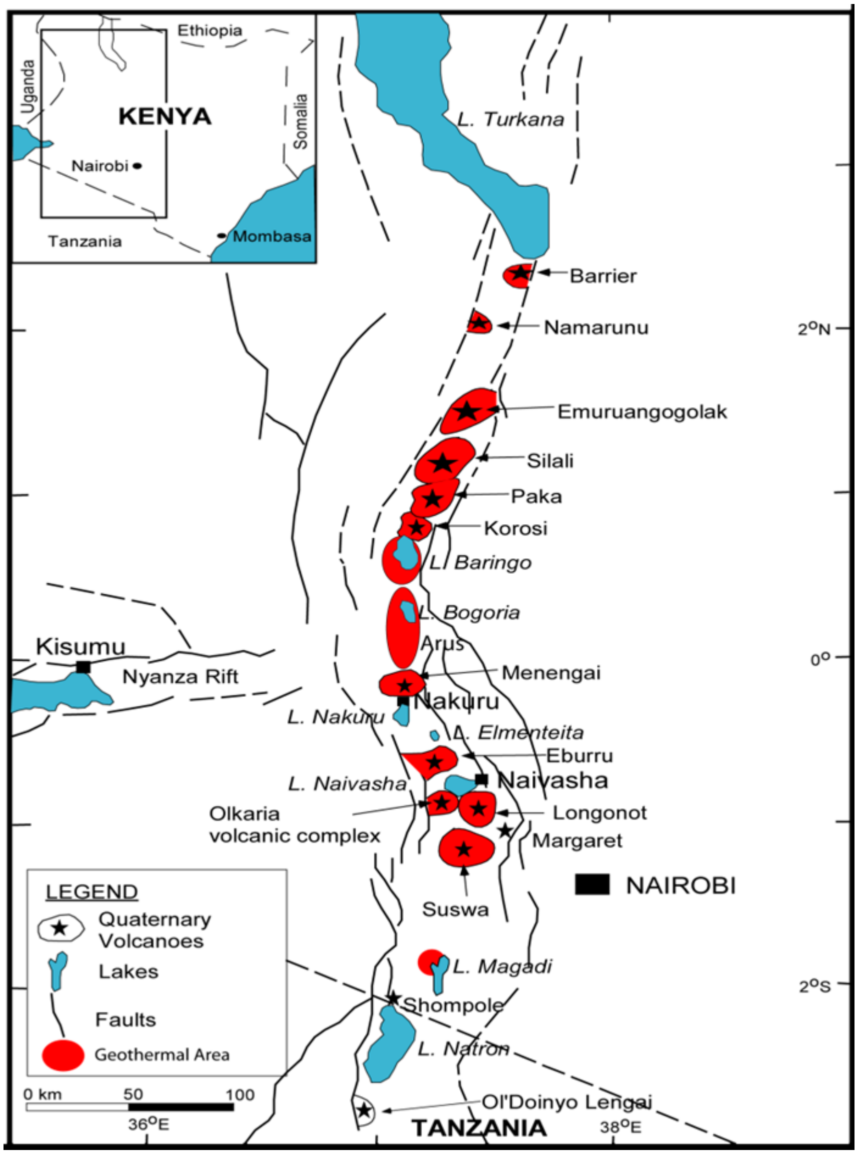

Figure 1: Map of Olkaria

1.2 Mode of Generation Employed by KenGen in the Olkaria Geothermal Field

KenGen has installed Flash Steam Power plants in the field. This involves drilling into the ground, up to a depth of 3,000m to tap hot fluids under high pressure. As this hot fluids flows up through wells in the ground, it is collected in a flash tank where drop in pressure causes the liquid to boil into steam.

The steam is separated from the liquid which is then used to run turbines which in turn generate power. The condensed steam is returned to the reservoir. KenGen has both convectional power plants, where steam is collected from a number of wells and piped to a central power plant, and well head generating plants, where a small power plant is constructed on the top of one well. Figure 2 below shows the 2 types of power plants in the field.

Figure 2: Convectional Power Plant (L) and Well Head Power Plant (R)

1.3 Chemical Composition of HDPE

High-density polyethylene (HDPE) or polyethylene high-density (PEHD) is a polyethylene thermoplastic made from petroleum. It is sometimes called "alkathene" or "polythene" when used for pipe production. With a high strength-to-density ratio, HDPE is used in the production of plastic bottles, corrosion-resistant piping, geo-membranes, and plastic lumber. HDPE is commonly recycled, and has the number "2" as its resin identification code. Figure 3 below identifies HDPE in its class of polymers.

HDPE is known for its large strength-to-density ratio. The density of HDPE can range from 0.93 to 0.97 g/cm3 or 970 kg/m3. Although the density of HDPE is only marginally higher than that of low-density polyethylene, HDPE has little branching, giving it stronger intermolecular forces and tensile strength than LDPE. The difference in strength exceeds the difference in density, giving HDPE a higher specific strength. It is also harder and more opaque and can withstand somewhat higher temperatures (120 °C/ 248 °F for short periods, 110 °C /230 °F continuously).

1.4 Current Places where steel is used in Olkaria Geothermal Field.

Steel pipes are used in transmitting of hot fluids, either from the well to the power plant, and also from the production well to the reinjection well. In a drilling site, steel casings are installed to carry the drilling fluid returns from the well to the drilling pond. In provision of drilling water, steel pipes are used in sizes ranging from 6” to 10”. Wellhead plants have been installed in seven different sites, and it is required that the brine be disposed of at different reinjection sites. So as to conform with the environmental and Kenya Wildlife Services regulations, the carbon steel water pipes that were available have been connected to dispose the brine. This has greatly reduced the number of water pipes available for provision of drilling water.

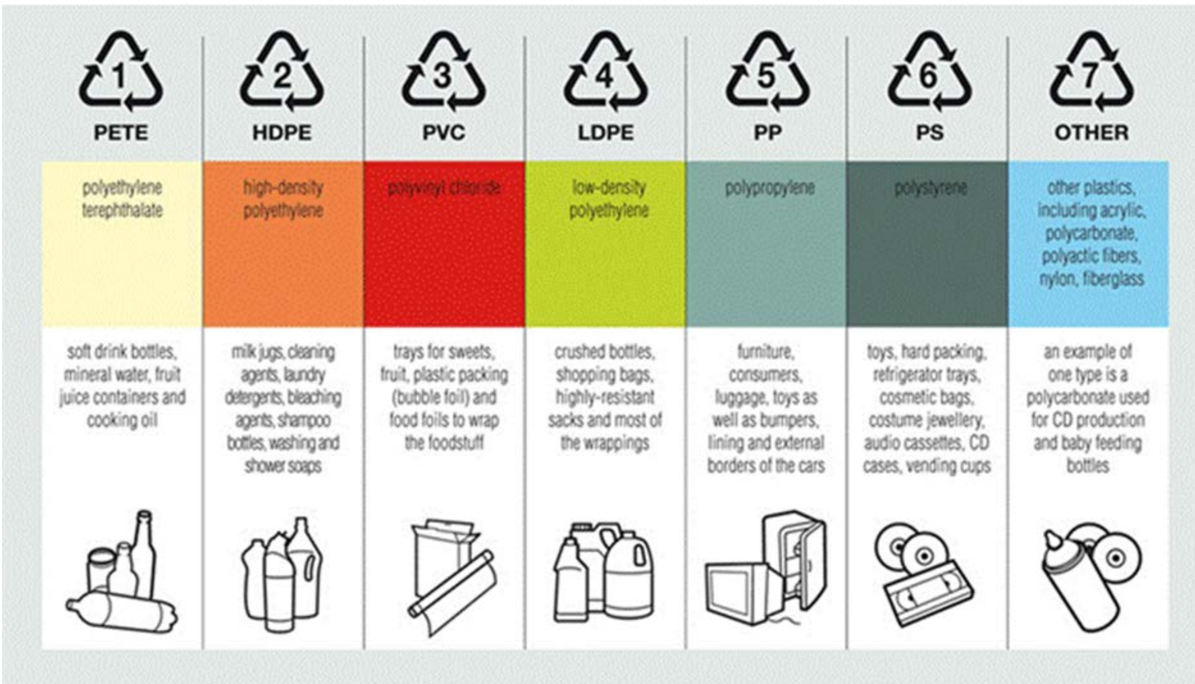

Figure 3: PE Polymers and Common Uses

2. Locations Where the Pipes can be Replaced

Different locations where carbon steel can be replaced with HDPE while giving an economic advantage have been identified and will be presented in a case by case basis. Calculations will also be shown where possible to justify the need for shift. In some cases, HDPE is the only alternative for long term use, given the chemical composition of the brine.

2.1 Reinjection of Brine produced at the Well-head Power Plants:

Well head power plants are an innovation of KenGen that ensures that we have early generation. Well Head generation has been adopted by KenGen because of the following major advantages (Ronoh Kibet, 2012):

a) Early return on investment; this technology represents a significant advantage over the deployment of traditional power plants enabling the early supply of electricity and importantly access to revenues earlier in the investment cycle

b) Optimal energy utilization; the independent well-head power plant enables optimum power to be produced from each individual well regardless of their differing outputs and characteristics. The concept negates the needs of traditional power plants for well redundancy or an excess steam buffer to cater for well failures and allows all wells to be utilized. The wellheads modular design also makes it possible to generate electricity from remote wells that are outside the topographical reach of large traditional plants.

c) Rapid deployment; the wellhead's modular design, based on standard manufactured components, allows for significantly reduced lead times and early power online. Delivery of power online can be reduced to within 12 months of ordering the first wellhead generator power plant and thereafter rapid deployment, at a rate of one wellhead generator plant per month, can be achieved.

d) Lower risk with modular flexibility; The wellhead generator modular power plant is delivered in 40-foot ISO containers and each module is ready made at the factory allowing for quick installation. It is designed to operate independently for each well, but can be organized in power farms to provide a similar power output to large traditional geothermal power plants.

e) In the event of a well failure, the wellhead generator is designed to be decommissioned, transported and redeployed on a second well, maximizing the return on investment. Equally importantly, the failed well can be returned to its original state thus preserving the environment.

f) Reduced cost per megawatt; The wellhead generator's modular design based on standard manufactured components enables a highly competitive capital price and allows for easy maintenance and access to spare parts.

g) Flexibility and adjustability in power generation; focusing on the characteristics of each well independently, the wellhead generator is able to adjust turbines to achieve a high level of power output efficiency, driving down electricity production costs.

h) Ease of operation and maintenance; The wellhead generator also deploys an advanced control system providing real-time operational data, allowing for early remediation action and preventative maintenance thus avoiding unnecessary downtime

To ensure compliance with the relevant environmental protection laws, KenGen used fresh water supply pipes to dispose the brine. Well head generators were initially meant to be temporary, but from the intensive drilling that has been done, KenGen has proved enough steam to ensure that the well heads are more permanent. They now have a design life of 15 years.

It has been established that HDPE pipes can replace steel pipes as a means of brine disposal. (Andrew Wedgner, 2015) published a paper detailing the viability of replacing steel with HDPE for condensate disposal. This was done at the Wayang Windu geothermal plant, which is owned and operated by Star Energy in Jakarta Indonesia. The plant was completed in 1999 and generates up to 227MW of electricity. Once the steam, which is used to generate the electricity using steam turbines, has cooled and condensed it is returned to the underground reservoir through condensate pipelines and injection wells. The condensate is very corrosive due to high levels of dissolved solids and the relatively high condensate temperatures, which typically reach 50°C. In addition, the Wayang Windu pipelines are laid in a hilly region and flow under gravity, which makes them prone to erosion. Therefore the corrosion and erosion of the steel pipelines carrying the condensate is a fact of life and after some years in operation that lead to regular repair and eventually replacement of the steel pipelines. The pipeline was originally designed using carbon steel as there was a lack of alternative materials and it was also assumed that corrosion would not be a major problem as the condensate water would have been substantially deoxygenated by the power station condenser prior to entering pipeline. The team went out to find a replacement that would use of a non-metallic pipe material, in order to avoid the corrosion problems with which they had become so familiar with. Figure 4 below shows the intensity of corrosion of steel pipes in the Wayang Windu steam field.

Figure 3: Corrosion of steel pipes at Wanyang Windu due to chemicals in condensate

The material selection process looked at the use of the following materials:

- High Density Polyethylene (HDPE)
- Polyvinylidene Fluoride (PVDF)
- Polypropylene (PP)
- Chlorinated Polyvinyl Chloride (CPVC)

In order to look at each material in a subjective manner, their relative performance against each of the following parameters was assessed.

- Mechanical strength
- Water and chemical resistance
- Erosion resistance
- UV degradation
- Ease and effectiveness of jointing systems
- Maintainability
- Total installed cost

The results from their study are as summarized in Table 1 below.

Table 1: Comparison of PE materials to replace steel

Parameter \ Material	HDPE	PVDF	PP	CPVC
Mechanical strength	Okay for 12 bar pressure and temperatures of 60°C.	Okay for 12 bar pressure and temperatures of 60°C.	Okay for 12 bar pressure and temperatures of 60°C.	Okay for 12 bar pressure and temperatures of 60°C.
Water and chemical resistance	Excellent to most chemicals	Excellent to most chemicals	Excellent to most chemicals	Limited resistance to Amines
Erosion resistance	Good resistance	Good resistance	Good resistance	Good resistance
UV degradation	Excellent because of carbon black content	Good	Degradable	Degradable
Ease and effectiveness of jointing systems	Easy and strong (Butt Fusion welding)	Easy and strong (Butt Fusion welding)	Easy and strong (Butt Fusion welding)	Not easy (Rubber rings or cemented joints)
Maintainability	Little maintenance	Little maintenance	Little maintenance	Little maintenance
Total installed cost	Least installation costs	Very expensive. 5 times the cost of HDPE	Higher than HDPE	Higher than HDPE

From the table above, the engineers chose PE100 (HDPE) as the best cost versus performance balance for that application and adopted it for the pipeline replacement project. The project was commissioned in July 2013 and has been operating without an incidence.

In the Kenyan case, HDPE provides a more attractive solution for the following two main reasons.

1. Cost – HDPE is expected to be cheaper than carbon steel, for an equivalent internal diameter of pipe, and pressure rating for a particular use. In addition, currently there are no manufacturers of seamless carbon steel pipes in the country. This means the carbon steel pipes have to be imported before they can be used. Meanwhile, we have HDPE pipes manufacturers in Kenya. Formed pipes occupy more space than the raw material that would form them. Hence the freight cost of importing formed pipes increases the delivered prices of the pipes.

2. Delivery time – given that the process of procuring any of the pie types would follow the public procurement process, from history goods imported from overseas take not less than 365 more days to arrive than goods procured in Kenya. Given that there are manufacturers in Kenya doing HDPE pipes to ISO standards, then this become a better option for this case.

A simple worked out case of using 8", schedule 20 Victaulic pipes (202.4mm internal diameter) and using 225mm PN 12.5, PE100 HDPE pipes for a 1km line is shown in table 2 below. The cost is shown in Kshs per km of waterline laid in Olkaria.

Table 2: Cost of carbon Steel versus HDPE

Cost of Buying and laying ID 202mm Victaulic pipe	7,776,729
Cost of Buying and laying ID 192mm HDPE pipe	3,633,333

From the table above, this translates to 53.3% savings in the cost of waterline for equivalent pipe sizes.

In addition to initial installation costs, HDPE is expected to have lower life costs. This is because HDPE does not corrode, hence there will be no replacements in its life and also the lower pumping costs. From the Hazen Williams equation of water flow, velocity of water flow (and hence pumping cost) through different pipe materials is defined by the equation 1 as:

$$V = k\, C\, R^{0.63} S^{0.54} \qquad (1)$$

- Where *V* is the velocity
- *k* is a conversion factor for the unit system (k = 1.318 for US customary units, k = 0.849 for SI units)
- *C* is a roughness coefficient
- *R* is the hydraulic radius
- *S* is the slope of the energy line (head loss per length of pipe or h_f/L)

The roughness coefficient C is material specific, and as defined above, directly determines the fluid velocity in different piping materials. From literature, the C values for carbon steel pipes and HDPE pipes are as in table 3 below:

Table 3: Hazen Williams "C" coefficient for 2 materials with age

Age (years)	**New**	**10**	**20**	**30**	**40**	**>50**
Carbon pipes	130	110	95	83	75	<60
HDPE Pipes	150	150	150	150	150	150

From table 3 above, it is clear that HDPE starts off as a smooth pipe, hence less costs in pumping and maintains the same pumping cost. Carbon pipes deteriorate with age, with pumping factor due to pipe roughness doubling at ages above 40 years. Hence HDPE has an edge over carbon pipes during the total life cycle of an installation.

HDPE has also been used in other industries to replace steel. From a Grey Literature(The Dow Chemical Corporation, 2009) HDPE has been proved to be a superior replacement for Carbon Steel in safety-related piping systems for nuclear power plants in the U.S. The issue with carbon steel has been two fold, a safety concern and a significant operational cost. According to the Electric Power Research Institute (EPRI), the physical maintenance of degraded steel water pipe systems, combined with the operational costs of shutting a plant down during repairs, is already costing some nuclear utilities up to $25 million per year (Stacey Burnett, 2009). The problem is particularly sensitive when the water pipe systems in question are safety-related, such as the Essential Service Water (ESW) systems that stand ready to cool a reactor when needed. In these systems, water-cooled secondary heat exchangers are used to maintain public safety and power generation continuity. AmerenUE, a subsidiary of Ameren Corporation, has pioneered the use of polyethylene (PE) as a new alternative to steel pipe ESW systems at its 1,200 megawatt Callaway Nuclear Power Plant. Polyethylene material does not corrode, rust, rot, pit, tuberculate or support biological growth, and it has an outstanding field performance record (for more than half a century) in water piping systems.

HDPE pipe was attractive to AmerenUE at Callaway for several reasons:

1. HDPE pipe is leak-free when produced and installed properly, even at joints, which can be as strong and leak-free as the pipe itself through use of the heat fusion joining technique.

2. HDPE is also corrosion and chemical resistant: it does not rust, rot, pit, corrode, tuberculate, or support biological growth.

3. It offers seismic resistance, in that it can safely accommodate repetitive pressure surges above its static pressure rating and is well-suited for seismic loading due to its natural flexibility.

4. HDPE is easier and more cost-efficient to install than carbon steel.

The superior chemical resistance of HDPE to corrosion as compared to steel makes it an attractive option for disposal of brine. HDPE has stood the safety test in nuclear power plants and it is easy for it to stand the tests in geothermal power plants.

2.2 Supply of Fresh Water to Permanent and Semi Permanent Installations

There are various installations currently supplied with steel and ductile iron piping in the Olkaria Geothermal Field. Well head plants will be online for at least 7 years. They are currently supplied with 6” carbon steel pipes. With enough storage for fire-fighting systems, the requirement for water supply is a 2” pipe. The cost savings that will be realized per km is as summarized in Table 4 below:

Table 4: Cost Comparison HDPE vs Carbon Steel Pipe Fresh Water Supply

Cost currently installed 6" Victaulic pipes	4,306,190
Cost of Buying and laying 63mm HDPE pipe	467,399
Cost savings per km	**3,838,791**

The Local Community in Olkaria that was resettled by KenGen is supplied with fresh water from the tanks at 900 series tanks. The map illustrated in figure 5 below shows the water supply network. The pipeline crosses some drifts, and during rainy seasons, due to rigidity of the galvanized iron pipes, the pipes are washed out. This leaves the community derived off water for some time, which leads to KenGen incurring costs due to constant repairs and supplying of water to the communities using water tankers. HDPE pipes can be supplied in lengths of 100M, and the waterline installed, such that there is no coupling inside or near the drifts. Due to flexibility of the HDPE pipes, it is expected to be more resistant to washouts caused by flash floods.

2.3 Drainage Casings in Drilling Sites

For a rig to be able to drill, a cellar is constructed where the top of the hole, as well as the host of the well head equipment is placed. During drilling, some of the drilling returns, together with water collecting on top of the well head drains into the cellar and flows into the pond through a drainage casing. The usual practice has been to use 20” steel casings for the drainage. There being no elevated temperatures in the returns, and the sole purpose of the casing being a conduit path for the fluids. The major consideration therefore becomes mechanical strength. A case for cheaper and easier to install HDPE pipe is discussed here.

Buried pipes experience loads from different sources. The following are the main forces expected to affect a buried pipe as shown in figure 6 below.

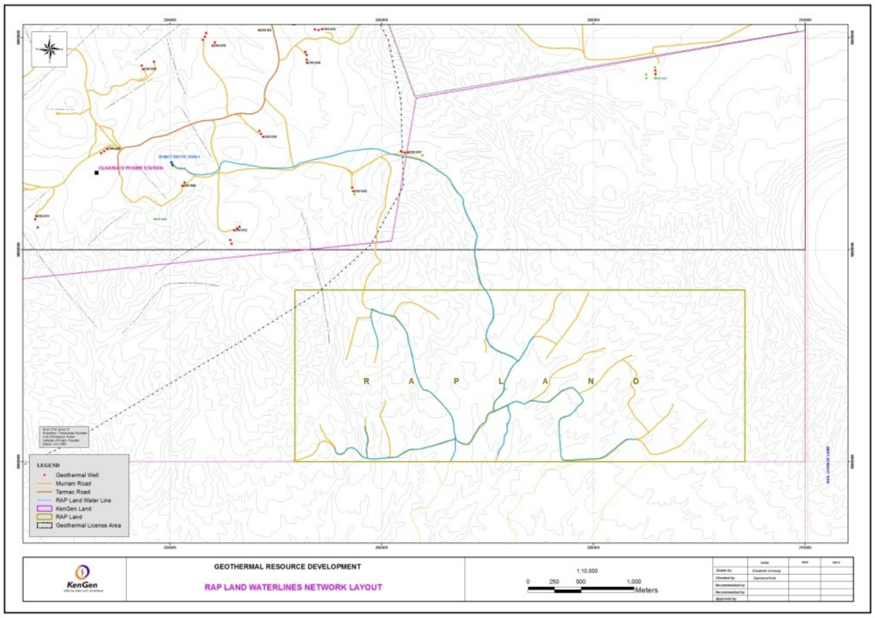

Figure 4: Map showing 900 series tanks and the water supply at RAP village

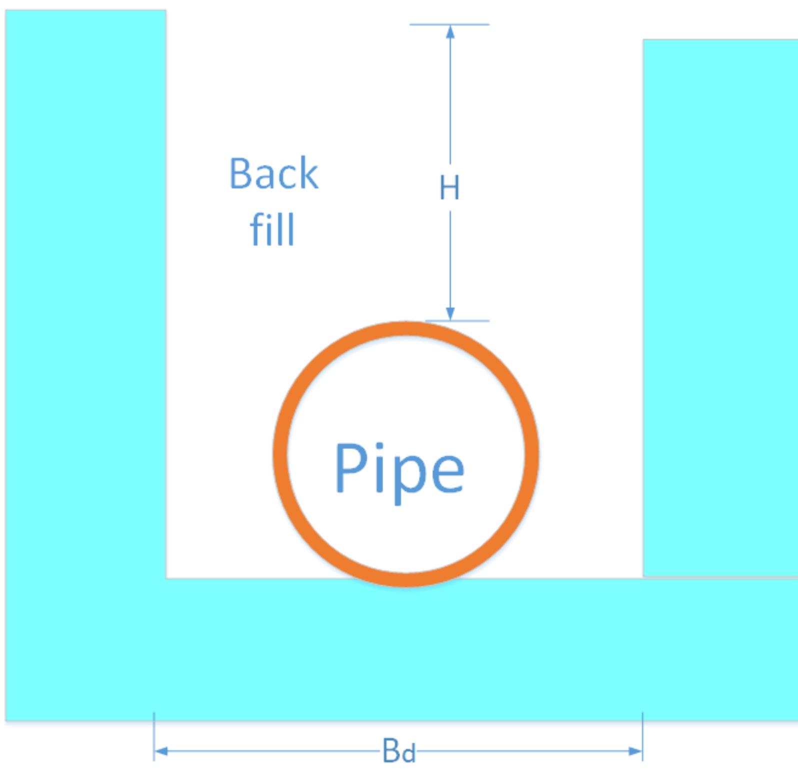

Figure 5: Illustration of a buried pipe with critical dimensions

1. Loads Due to Backfill

Backfill loads on a pipe depend on:

- Trench width
- Depth of excavation
- Unit weight of the fill material
- Frictional characteristics of the backfill

Due to the origin of the formulas in use, imperial units have been adopted for calculations. Here, we will take a case example using a 16” diameter HDPE pipe. The case to consider will be that of a Standard Installation – Trench or Embankment as explained in (Plastic Pipes Institute) and The Modified Iowa Formula will be used.

The formula for calculating prism load or geostatic stress is as shown in equation 2.

$$P_E = wH \quad (2)$$

where P_E is vertical soil pressure due to earth load in psf (lb/ft^2), w unit weight of soil in pcf (lb/ft^3)

and H is the depth of cover in ft.

$$P_E = 120 * 3.58 = 429.6\ lb/ft^2$$

2. Live Loads on the site

During a rig move, the heaviest equipment that crosses the cellar drainage is a 50 ton crane. This is used in placement and arrangement of the equipment around the rig.

From calculations as attached in Appendix 1, the total Live Load 220 lb/ft^2.

3. Superficial / Surcharge Loads on buried pipe

These are loads produced by structures that are built on top of the trench or that cross the trench.

In the rig arrangement, the heaviest structure that lies above the drainage casing is a mud tank. When full of viscous mud (density of 1800kg/m^3), the total weight is about 125 tons (275,578 lb). The dimensions of the mud tank are 12.5m x 2.5m x 3m (L x W x H). The area of the load is 31.25m^2 (336.37 ft^2). This gives a load distribution of 819.3 lb/ft^2.

From Appendix 2 and the dimensions above, the maximum portion of the load reaching the pipe is 0.172. From equation 3 below, we get the vertical soil pressure due to surcharge as.

$$P_S = 4 I_V W_S \quad (3)$$

$$P_S = 4 * 0.172 * 819 = 563.7\ lb/ft^2$$

From Spangler's Modified Iowa Formula for use with solid wall PE pipe (equation 4 below), we are able to get deflection on the pipe due to the 3 loads calculated above.

$$\frac{\Delta X}{D_M} = \frac{1}{144}\left(\frac{K_{BED}\, L_{DL} P_E + K_{BED} P_L}{\frac{2E}{3}\left(\frac{1}{DR - 1}\right)^3 + 0.061 F_S E'} \right) \qquad (4)$$

ΔX = Horizontal deflection, in

K_{BED} = Bedding factor, typically 0.1

L_{DL} = Deflection lag factor

P_E = Vertical soil pressure due to earth load, psf

P_L = Vertical soil pressure due to live load, psf

E = Apparent modulus of elasticity of pipe material, lb/in2

E' =Modulus of Soil reaction, psi

F_S = Soil Support Factor

R_{SC} = Ring Stiffness Constant, lb/ft

D_R = Dimension Ratio, OD/t

D_M = Mean diameter (DI+2z or DO-t), in

z = Centroid of wall section, in

t = Minimum wall thickness, in

D_I = pipe inside diameter, in

D_O = pipe outside diameter, in

Calculations for a 16" PN6, DR26 PE100 HDPE pipe passes the deflection test (less than 5%). Results have been calculated from an online tool at http://www.hdpipecalc.com/

Appendix 1 shows screenshots of the results.

Hence from the calculations above, the pipe can be used as a cellar drainage casing.

Potential savings from changing from steel to HDPE are as in table 5 below.

Table 5: Savings while changing from Steel to HDPE in cellar drainage

Cost of 20" steel casing per meter	11,610
Cost of 16" PE100 PN6 pipe per meter	7,102
Cost Savings per M	4,508

3. Findings and Recommendation

From the above discussion, the following findings were made and the recommendations alongside them.

i. Flashed brine from well head generating has a lower pressure and temperature. This means that as the brine cools, the solids dissolved in the solution deposits. Carbon steel is not a suitable material for handling this fluid with increased chemical concentration. To avoid corrosion, deposition, hardening of rubber gaskets, it is recommended that all brine should be re-injected using HDPE pipes.

ii. In addition to the corrosion resistance of the HDPE as a material, the price per unit length for a given pressure range is lower than that of carbon steel. Hence HDPE being a cheaper option than carbon steel is recommended for all brine disposal uses.

iii. Due to the terrain and nature of the field, HDPE pipes are recommended for fresh water supply to the villages in the GOVC. This gives the pipeline the flexibility that it requires during flash flooding in the field. Rigid metal pipes are bound to be washed away from time to time, and the interruption in water supply plus repair costs are expensive to KenGen.

iv. The replacement of carbon casing in a cellar drainage should be investigated by KenGen. The cost advantage, and the availability of the HDPE pipes locally due to having manufacturers in Kenya means that the company can procure what is needed instead of stocking casings for a large number of wells.

REFERENCES

Andrew Wedgner, G. G. (2015). The use of PE100 polyethylene to minimise condensate pipeline corrosion at the Star Energy Wayang Windu geothermal power plant. *Proceedings Indonesia International Geothermal Convention & Exhibition 2015.* Jakarta Convention Center, Indonesia – August 19th – 21st, 2015.

Plastic Pipes Institute. (n.d.). *Publications PE Handbook 2nd Edition.* Retrieved October 12, 2015, from Plastic Pipe Institute: http://plasticpipe.org/publications/pe-handbook.html

Ronoh Kibet, R. B. (2012). KenGen's Wellhead Technology & Business Insight. *KenGen's G2G Technical Seminar*. Nairobi: KenGen.

Stacey Burnett, B. C. (2009). *EPRI 2009 Portfolio, Balance of Plant Corrosion.* California: Electric Power Research insitute.

The Dow Chemical Corporation. (2009). *CONTINUUM™ Bimodal HDPE Performance Report.* Michigan: The Dow Chemical Company.

APPENDIX 1 SCREENSHOTS OF CALCULATION RESULTS

Information

Date	07-15-2016
Project	Cellar Drainage
Engineer Name	G. Maingi
Comments	Diameter 16" SDR 26 Wall Thickness 17mm

Variables

E'	1000	PIModulus of Soil Reaction, psi
D_o	16	Pipe Outside Diameter, in
DR	26	Dimension Ratio
D_M	15.348	Mean Pipe Diameter, in
E	29000	Apparent Modulus of Elasticity, psi
w	0	Soil Density, lb/ft³
K_{BED}	0.1	Bedding Factor, typically 0.1
L_{LD}	1	Deflection Lag Factor
F_S	1	Soil Support Factor (refer to Chapter 6, Tables 3-9 and 3-10 for additional factors)
H	3.58	Height of Soil Cover above pipe, ft
H_W	0	Height of water table above pipe, ft
P_S	564	Total Static Load, psf

Total Live Load, psi: Live Load Without Pavement

P_L	220	Total Live Load, psf

Result

P_E	564	Earth Load on Pipe, psf
P_T	784	Earth Load on Pipe, psf
ΔX	0.134	Vertical Deflection, in
d	0.87	Percent Vertical Defelction, %
P_{WC}	4955	Crictical Collapse Pressure, psf
SF	6.32	Safety Factor against Constrained Buckling

APPENDIX 2 Influence Values for Distributed Loads

M/H	N/H													
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.5	2.0	∞
0.1	0.005	0.009	0.013	0.017	0.020	0.022	0.024	0.026	0.027	0.028	0.029	0.030	0.031	0.032
0.2	0.009	0.018	0.026	0.033	0.039	0.043	0.047	0.050	0.053	0.055	0.057	0.060	0.061	0.062
0.3	0.013	0.026	0.037	0.047	0.056	0.063	0.069	0.073	0.077	0.079	0.083	0.086	0.089	0.090
0.4	0.017	0.033	0.047	0.060	0.071	0.080	0.087	0.093	0.098	0.101	0.106	0.110	0.113	0.115
0.5	0.020	0.039	0.056	0.071	0.084	0.095	0.103	0.110	0.116	0.120	0.126	0.131	0.135	0.137
0.6	0.022	0.043	0.063	0.080	0.095	0.107	0.117	0.125	0.131	0.136	0.143	0.149	0.153	0.156
0.7	0.024	0.047	0.069	0.087	0.103	0.117	0.128	0.137	0.144	0.149	0.157	0.164	0.169	0.172
0.8	0.026	0.050	0.073	0.093	0.110	0.125	0.137	0.146	0.154	0.160	0.168	0.176	0.181	0.185
0.9	0.027	0.053	0.077	0.098	0.116	0.131	0.144	0.154	0.162	0.168	0.178	0.186	0.192	0.196
1.0	0.028	0.055	0.079	0.101	0.120	0.136	0.149	0.160	0.168	0.175	0.185	0.194	0.200	0.205
1.2	0.029	0.057	0.083	0.106	0.126	0.143	0.157	0.168	0.178	0.185	0.196	0.205	0.209	0.212
1.5	0.030	0.060	0.086	0.110	0.131	0.149	0.164	0.176	0.186	0.194	0.205	0.211	0.216	0.223
2.0	0.031	0.061	0.088	0.113	0.135	0.153	0.169	0.181	0.192	0.200	0.209	0.216	0.232	0.240
∞	0.032	0.062	0.089	0.116	0.137	0.156	0.172	0.185	0.196	0.205	0.212	0.223	0.240	0.250