Drainage Pipe Deflection for High Heaps [1]

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Drainage pipes form an integral part of most leach pad designs. For these systems to function properly the pipes must maintain their integrity for the life of the heap (i.e., through the ultimate heap height). Pipe survivability at depth is dependent on the deformation of the adjacent soil and the properties of the pipe. The two most common methods of calculating pipe deflection, Spangler's equation and the Burns-Richard solution, both rely on soil properties as well as pipe properties in their predictive algorithms. However, both models as well as the hybrids derived from them were developed for classical civil engineering applications: maximum burial depths of 5 to 20 meters beneath rigid structures such as pavements or buildings. Thus, these models have been calibrated against known field performance under these conditions, and typically with maximum allowable vertical deflections of 5 to 7.5 percent of pipe diameter.

Using the Burns-Richard solution, for example, a corrugated dual-wall polyethylene pipe (150 mm nominal diameter) reaches the maximum allowable conditions at about 24 m of burial, corresponding to 7.5% vertical deflection. However, such limiting heights are of little value in heap leach design, where most new projects consider ultimate heights of 75 to 100 m. With new designs considering 145 m and higher, new standards are needed. Modern polyethylene pipes are clearly more flexible and strain-tolerant than their rigid predecessors. Thus, higher limiting deflections are appropriate. One limiting factor, however, is full collapse of the pipe with resulting large reduction in available flow area, loss of structural capacity, and possibility for joint separation. Commonly called buckling, this is were the pipe turns in on it's self in "binocular" fashion (see Figure 2b). Thus, one could use the load that causes buckling as the ultimate load, and then apply a factor of safety to determine the allowable load.

Laboratory Deflection Testing

Actual high-load deflection tests have been performed by the author's laboratory up to loads of 2,000 kPa (about 100 to 120 m of simulated heap depth) on approximately 30 combinations of pipe and soil. The tests are run in a box 750 mm wide by 600 mm deep

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by 500 mm high. Double-wall, smooth bore, corrugated PE pipe has been tested in nominal diameters of 100 mm, 150 mm and 180 mm, representing the most common drainage pipes employed in heap leaching. Using either actual or simulated overliner gravel, compactions were varied from 78% to 88% of standard Proctor, represented the range of typical installations seen in the field. The test results have shown vertical deformations ranging from 6% to 54% of the initial pipe diameter, with a strong correlation existing between the initial degree of compaction and the vertical deformation. Of course, compacting the overliner near the pipe increases the risk of damage to the geomembrane, not to mention construction costs. Nevertheless, for high heaps the laboratory data and conventional modeling indicate that this is an essential step for drainage pipe survivability.

Photo 1: Pipe Deflection Test Apparatus

Photo 2: Pipe after 2,000 kPa Loading

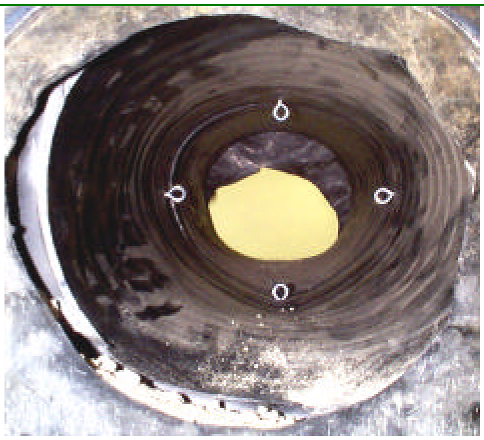


Figure 1 shows a sample of this data. Up to approximately 30% vertical deformation (+/-5% depending on the pipe weight and structural design), the pipe would show dimpling from the adjacent gravel, but no noticeable buckling. Above this level the pipe would begin to exhibit buckling and approach a binocular shape (see Figure 2b). Obviously, as overburden load increases above 2,000 kPa the survivability of pipes will be challenged even further.

The laboratory deflection results have been compared to the Burns-Richard solution. Using a calibrated value for soil modulus (notably the most difficult parameter to define), the Burns-Richard solution appears to be reliable to higher loads (see Table 1). At least for short-term loading and normal ambient temperatures.

Figure 1: Typical Load-Deflection Curves for Dual-Wall PE Pipe

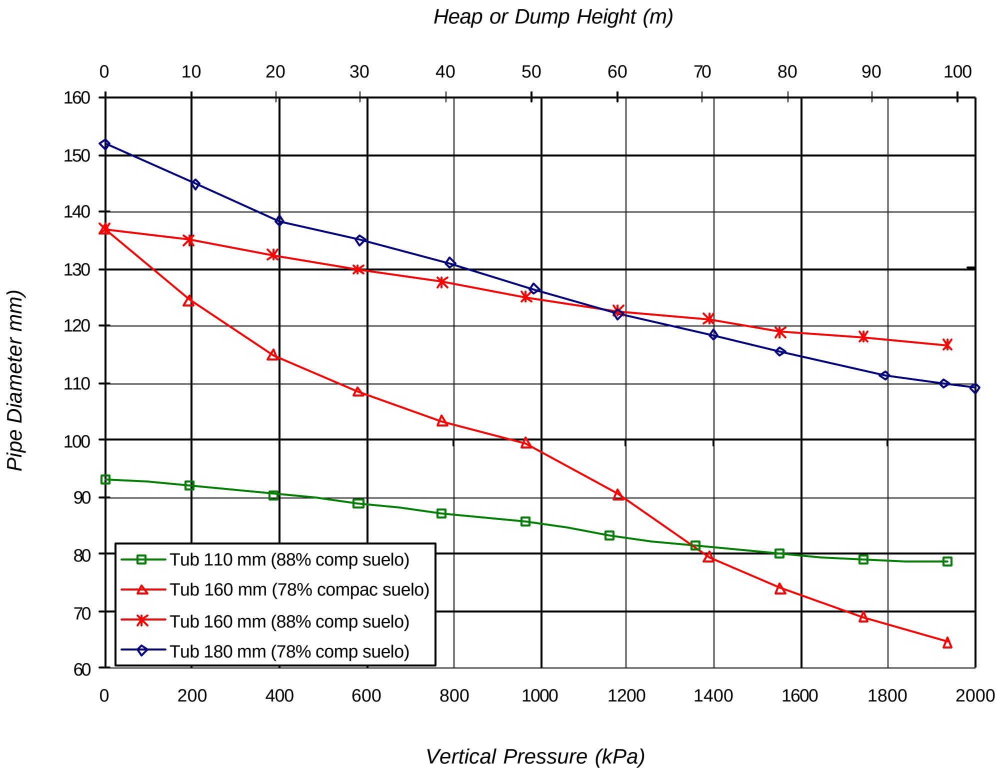
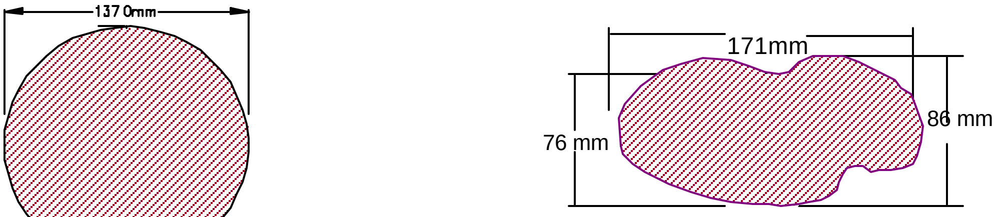


Figure 2: Post-test Pipe Cross-Section after 2,000 kPa Loading



(a) With 88% proctor compaction in haunch , 15% vertical deflection

(b) With 78% procto r compaction in haunch , 54% vertical deflection

Creep and High Temperatures

Assuming that the Burns-Richard solution holds true for these extreme depths, as the laboratory data suggests, then the effect of long-term loading and high temperatures can be estimated using this same model. Modulus of elasticity effects pipe stiffness, and this modulus is both time- and temperature-dependent. A 50% reduction in modulus can result by increasing the temperature from 23 °C to 50 °C. Recent modeling of sulfide copper heaps suggests that temperatures of 40 to 50 °C occur near the drainage system. Long-term creep effects, regardless of temperature, can reduce the modulus by a factor of four or five. Table 1 summarizes the Burns-Richard solutions for both normal and long-term, elevated temperature conditions. These results assume that the soil properties do not change with time or temperature; an assumption that may not be conservative.

Table 1: Laboratory v. Calculated Deflections – 160 mm Dual Wall Pipe

Heap Height	**Vertical Deflection, %**		
	Laboratory	**Burns-Richard**	**Burns-Richard**
m	23°C, short-term	23°C, short-term	50°C, long-term
20	4.3	5.0	8.0
40	7.2	8.6	13.3
60	11.6	11.6	17.6
80	13.8	14.3	21.5
100	15.2	16.8	24.9
120	19.2	19.2	28.1
140	ND	21.4	31.0

Note: Gravel compacted to 88% standard Proctor. Soil modulus calibrated at 120 m.

Using 30% as the "typical" buckling deflection (if there is such a thing) and the predictions from Burns-Richard, it's clear that pipes considered safe for short-term, low temperature installations (deflection ~ 21% at 140 m burial) may not be safe under actual temperatures and long-term loading (deflection ~ 31%).

Table 2: Modulus of Elasticity of Polyethylene

Temperature	**Modulus of Elasticity, mPa**	
^{o}C	Short-Term	Long-Term
23	990	240
30	860	200
45	640	120
50	510	110

Summary

Heap leaching requires reliable drainage of the pregnant solution, not only for optimum metal recovery but also for stability and leakage control Modern technology has pushed the “typical” heap height to 100 meters, and plans are to go even deeper. With designs currently in process for heaps of over 145 meters, the limits of known pipe performance have been long passed. The standard methods for designing buried pipes are no longer applicable, yet no new standard method has come forth. The author proposes a new standard, based on the buckling deflection of the pipe. For this method to be reliable, however, the soil properties must be well known and the selected numerical model calibrated to actual laboratory data. Laboratory testing is currently in progress to measure pipe deflections at elevated temperatures and higher loads. With calibration and an increasing data base, this model can be used to evaluate changes such as creep, elevated temperature, differing pipe diameters, various heap depths, differing overliner materials and degrees of compaction.