TECHNICAL NOTES

Concrete encasement of flexible plastics pipes

Scope

The document is applicable for the following:

- Buried PE100 RC solid wall gravity drainage and pressure pipes
- Side support of pipes in HK applications (typically due to proximity to other services)
- Burial design in compliance with BS 9295 and BSEN 1295

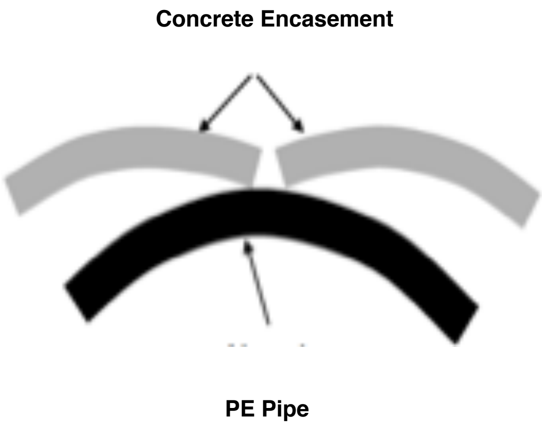
Quick Summary

According to: ***BS 9295:2010 Guide to the structural design of buried pipelines*** Clause A.14.3: Flexible (Polyethylene) pipes should not be encased with concrete unless special conditions exist, it further adds; "*when a concrete surround is used, it shall be a designed to carry the full hoop load of the soil and include steel reinforcing*".

If the design criteria for flexible pipes laid out in BS 9295 is abandoned by encasing a PE pipe with concrete, then such encasement **must be structurally designed to take the full static & dynamic loads found over the life of the pipe** (such as a reinforced concrete pipe, culvert, or reinforced concrete slab covering the pipe). In this case, the PE pipe is simply acting as a non-structural liner. This is not the purpose or economic rationale behind the use of flexible pipes in wastewater and there are far cheaper methods of achieving a thin liner within a concrete structure, if this is the design objective.

Adding unreinforced concrete encasement (this is typical practice in HK with rigid pipes) to a flexible Polyethylene pipe changes a flexible pipe design into a rigid pipe design. This renders the performance benefits from polyethylene pipes void. Contrary to traditional thinking about using a "belt & braces" approach to rigid pipe encasement, encasement is generally detrimental to the life of a flexible pipe, as the unreinforced concrete encasement cracks, rolls into the PE pipes surface, creating point loads on the PE which lead to slow crack growth failures.

Concrete encasement of PE Pipe is unnecessary and is likely to be detrimental to performance, durability and the operating life of the pipeline.



Unreinforced Concrete encasement surrounding a PE pipe will always crack because the PE pipe flexes under load and the concrete is not structurally strong enough to support the static & dynamic loads. Once it flexes, it cracks and the risk is that it rolls into the PE pipe causing point loads on the pipes surface. PE 100 RC drainage pipes are designed to be backfilled with excavated soils.

Detailed Explanation

Three potential problems arise when encasing Polyethylene pipes in concrete:

- increased strain
- point loading
- temperature

Designers and installers should be aware of these issues and although the recommendation to not encase flexible pipes is already covered in BS 9295: 2010 in clause A.14.3, it does not address the reasons and assumes that designers are aware of the negative effect encasement may have on flexible pipes.

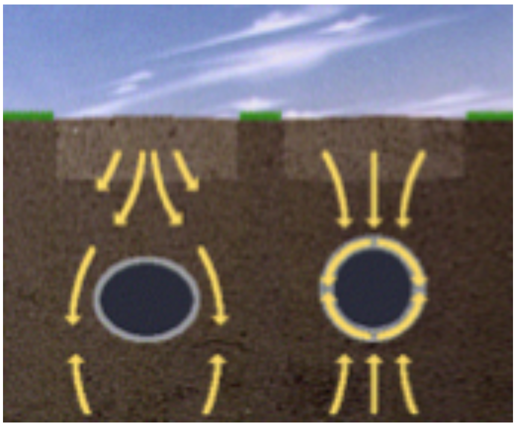
Increased Strain

BS 9295:2010, Clause A.14.3

In general, concrete surround (concrete encasement) is not normally needed for flexible pipes. Where plastics pipes under internal pressure are surrounded in concrete, some, if not all of the hoop stress in the pipe is transferred into the concrete, which is typically much stiffer than a flexible pipe. The designer will need to check specific cases but, except in the case of small pipe diameters (<DN150) the concrete encasement must include longitudinal and hoop steel reinforcement in order to carry the load being transferred to it. Additionally, the PE pipe will require a soft compressible material wrapped around the pipe at both entry and exit from the concrete surround to provide a transition from the rigid surround. The addition of steel to concrete encasement is effectively constructing a rudimentary reinforced concrete pipe, this adds cost and negates the point of having a PE pipe.

Unless the encasement is reinforced properly, the concrete surround is detrimental to the short and long term performance of a flexible plastic pipe and is likely to lead to premature failure of PE pipe through concrete point loading on the pipe. This is contrary to traditional thinking in Hong Kong relating to the installation of rigid pipes. The practice was always to add concrete encasement around ceramic clay (VCP) or (reinforced Concrete) RCP pipes, to further enhance the pipes inherent rigidity after installation, where the worst loading conditions are experienced. In this case, concrete encasement is acceptable, as both the pipe and the concrete are rigid materials. For PE, this logic does not apply, as a flexible pipe surrenders its hoop load to the more rigid concrete. (refer the notes below Table 1, BS 9295:2010).

The behaviour of flexible and rigid pipes are quite different, both in the short term (30 days after installation) and medium term settlement (2 years after installation). These differences are specifically detailed in the illustration given in BS 9295:2010 Figure 2, however the illustration is not well explained.



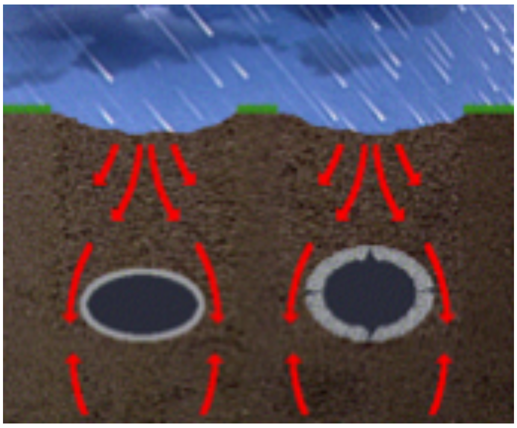
A rigid pipe is stiffer than the surrounding soil and when consolidation of the backfill takes place in the pipe zone, the soil to the sides of the pipe tends to settle more than the soil over the pipe.

By soil friction, load is transferred to the column of soil over the pipe (geostatic load,) meaning that the pipe is attracting more load than just the geostatic load. In response to this, a rigid pipe might settle marginally into its bedding.

A flexible pipe is less stiff than the surrounding soil, so when buried, the column of soil over the flexible pipe settles more than the columns of soil to the sides.

The effect of this is that the flexible pipe will deflect on loading but will also tend to shed load away from itself. (Ref: BS9295 Table 1 notes)

Figure 1 – short term pipe settlement (30 Days)



The left illustration is a flexible pipe, the right a rigid pipe. Figure 1 is the condition immediately after installation, Figure 2 is the condition after settlement approximately 2 years. The rigid pipe has been unable to withstand the vertical soil loads and has cracked during short-term settlement. After cracking the load on the rigid pipe will tend to shed away from itself and no further change is expected, however the damage to the rigid pipe has been done, it is cracked & failing.

The effect of concrete encasement on a flexible pipe is the same as an insufficiently strong rigid pipe. Because the encasement is unreinforced it is unable to withstand the initial load, it cracks around the PE pipe and the sharp edges of the concrete surround penetrate onto the PE pipe. The design now reverts to a flexible pipe design, however the point loading of the concrete onto the PE is detrimental, because the loads on the PE increase as the Concrete is 16% heavier than the design soil load of 19.6Kn/m^2.

Figure 2 – Medium term pipe settlement (2 years)

Point Loading

Point loading of PE by cracked concrete surround is highly likely to lead to pipe failure due to Slow Crack Growth. SCG is well documented and is the most typical medium to long term failure mode for PE pipes. Such failure risk is reduced by using PE100 RC (Resistant to Crack) compounds, never the less point loading is not desirable and should be avoided, especially from the unnecessary application of a concrete surround.

Figure 3 - Typical lab examples of point loads on PE pipes, and CCTV camera showing point load in service

Without engaging in extensive discussion on the causes & effects of slow crack growth, point loading from cracked concrete surround has two primary negative effects:

1. The load applied to the pipe by the cracked concrete is higher than the soil loads for which the pipes were designed (19.6Kn/m^2 vs. 23.5Kn/m^2) because the mass of the concrete is heavier this adds unnecessary additional loads to the flexible pipe over its life therefore increasing stress over time.
2. The point load causes internal surface tension of the PE leading to internal cracking. Below progression of a point load on PE pipe over time can be seen below in 10,000 Hours of accelerated testing at 80^{o} C

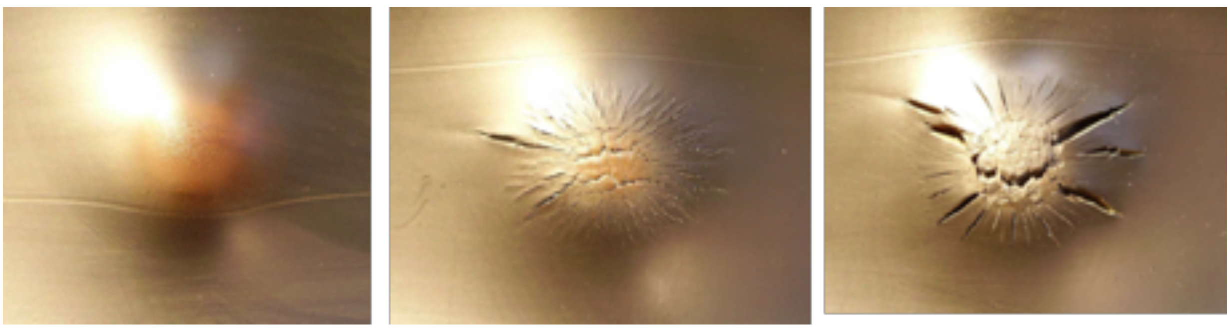


Figure 4 – Internal pictures of the progression of an external point load on a PE pipe over 10,000 Hrs accelerated test.

Temperature

Heat created during the hydration of cement products depends on numerous factors, including the type and composition of cement, the proportions of the mix and the ambient temperatures. The last factor is very important, since higher temperatures generate faster reactions in the concrete this creates more rapid heat evolution, the result is that the concrete cures faster, creating even more heat and this can invoke a runaway effect with excessive temperatures being created.

The actual temperatures reached depend on dissipation rates. In large dimension mass concrete, temperatures of 50°C are not uncommon. It should be noted that heat is created during the entire hydration process and it may be days before maximum temperature is reached.

Heat causes PE to expand in diameter and to reduce in strength, if the concrete encasement is unreinforced the PE pipe expanding due to heat will crack the surround during the curing process. If the concrete surround has a larger mass, it applies excessive load to the pipe. The elevated temperature causes a reduction the PE Maximum Rated Strength (MRS) of the pipe, this may cause the pipe to buckle – both these scenarios result in points loads described in point 2 above. In low SN rated pipes structural strength is rapidly lost to the rising temperature and can lead to ovality and loss of cross sectional area (oval pipes) although this is less likely to occur in higher SN rated pipes (SDR17) typical used in Hong Kong.

Summary & Conclusions

BS 9296 also goes to some length to explain the negative issues with using 'lean concrete' (5Mpa strength concrete) as a surround around flexible pipes in clause A.14.1:

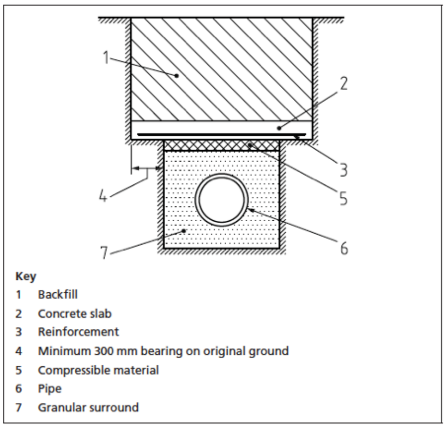
"…In some cases, it may be considered that the best solution in the circumstances is to backfill a trench with lean concrete. Such a decision should not be taken lightly, and any use of lean concrete backfill as a ploy to compensate for poor workmanship and lack of supervision will only lead to later difficulties…"

PE pipes do not require or benefit any way from being encased by a concrete surround, in fact it can be quite detrimental to the pipes long term service life & performance, alternates to concrete surrounds:

- If the static or dynamic loads are too great or the burial depth is too great for the pipes rated strength, then use a higher SN rated pipe (ie: Change from SDR 17 to SDR 11 / SN 24 to SN100 Pipe),
- If the burial depth is too shallow (< 0.6m) use a concrete reinforced slab design as given in BS 9295 Figure A.9 - Protection of shallow pipeline with a slab as shown above.

References

1. British Standard 9295: 2010 Guide to the structural design of buried pipelines
2. British / European Norm Standard 1295
3. Vinadex Pty Ltd Technical Note VX-TN-12J



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