7. Structural Design Aspects of a Sea Outfall at Grimsby (England)

Owner:	*The Lincoln Division of Anglian Water*
Design Engineer:	*Sir Frederick Snow and Partners, London*
Construction:	*Sir Alfred McAlpine and Services and Pipelines Ltd.*
Service Date:	*1983*

The Pyewipe long sea outfall at Grimsby, South Humberside in England is designed to discharge 6.34 m^3/s of sewage into the deeper channels of the Humber Estuary. The 2000 mm internal diameter pipeline of approximately 3 km length is the largest currently constructed in Europe by the bottom pull-method. This paper describes the design of the pipeline in relation to pipe wall thickness, internal and external protection against corrosion and support provided by the backfill placed underwater.

Background

The Pyewipe outfall is designed to discharge the foul sewage from large areas of the towns of Grimsby and Cleethorpes, with a domestic population of 170 000 on the south bank of the River Humber. The main industries in the area are associated with the areas history as a fishing centre, and hence are fish processing, food processing, supply industries and some chemical industry. Cleethropes which has a long sandy beach is a tourist resort.

The new outfall formed the third phase of five in Anglian Water's plans to rationalize the then existing inadequate combined sewage facilities which resulted in replacing two short outfalls by the new single long pipeline which is preceded by preliminary treatment.

Size and material

Many options for pipe material were considered to meet the criteria:

a) Economic to install
b) Reliable in service for a design life of 100 years
c) A tried and tested method of construction
d) Strong enough to resist installation forces
e) Available in the required diameter
f) Resistant to the potentially highly acidid industrial effluents.

The selected pipe construction was a composite of steel with an internal glass reinforced plastic (GRP) liner sleeve. A concrete weight coat for negative buoyancy of 185 mm thickness was applied to the 2.24 m o.d. steel pipe over a bitumen wrapping. The average 36 mm annular space between the GRP pipe and the steel was filled with PFA-cement grout (Fig. 1).

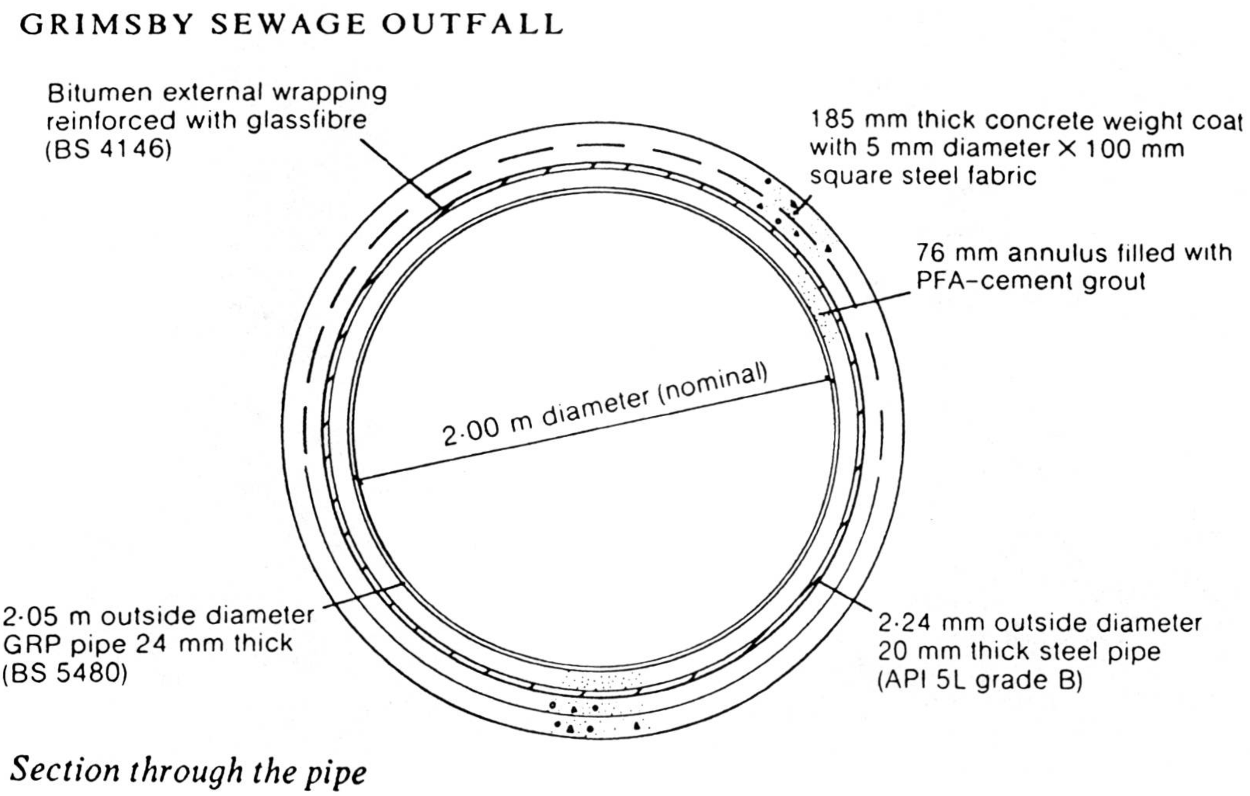

Fig. 1 Cross section drawing of composite pipe

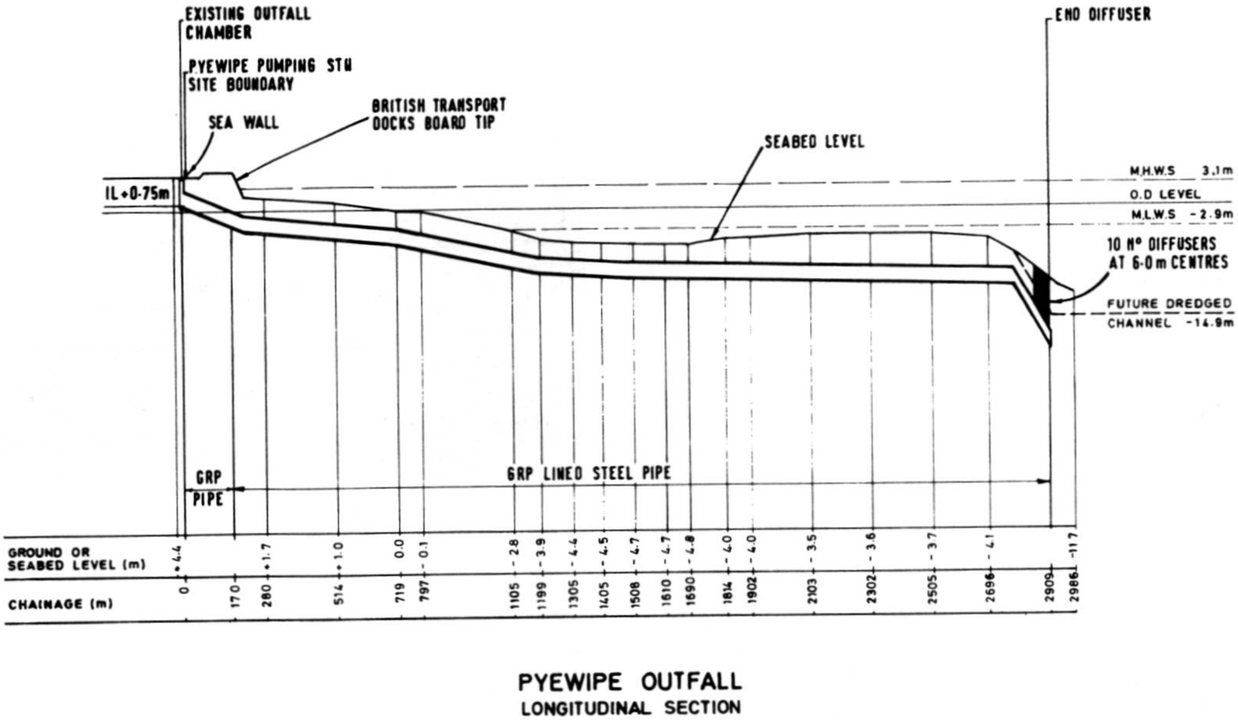

Fig. 2 Longitudinal section

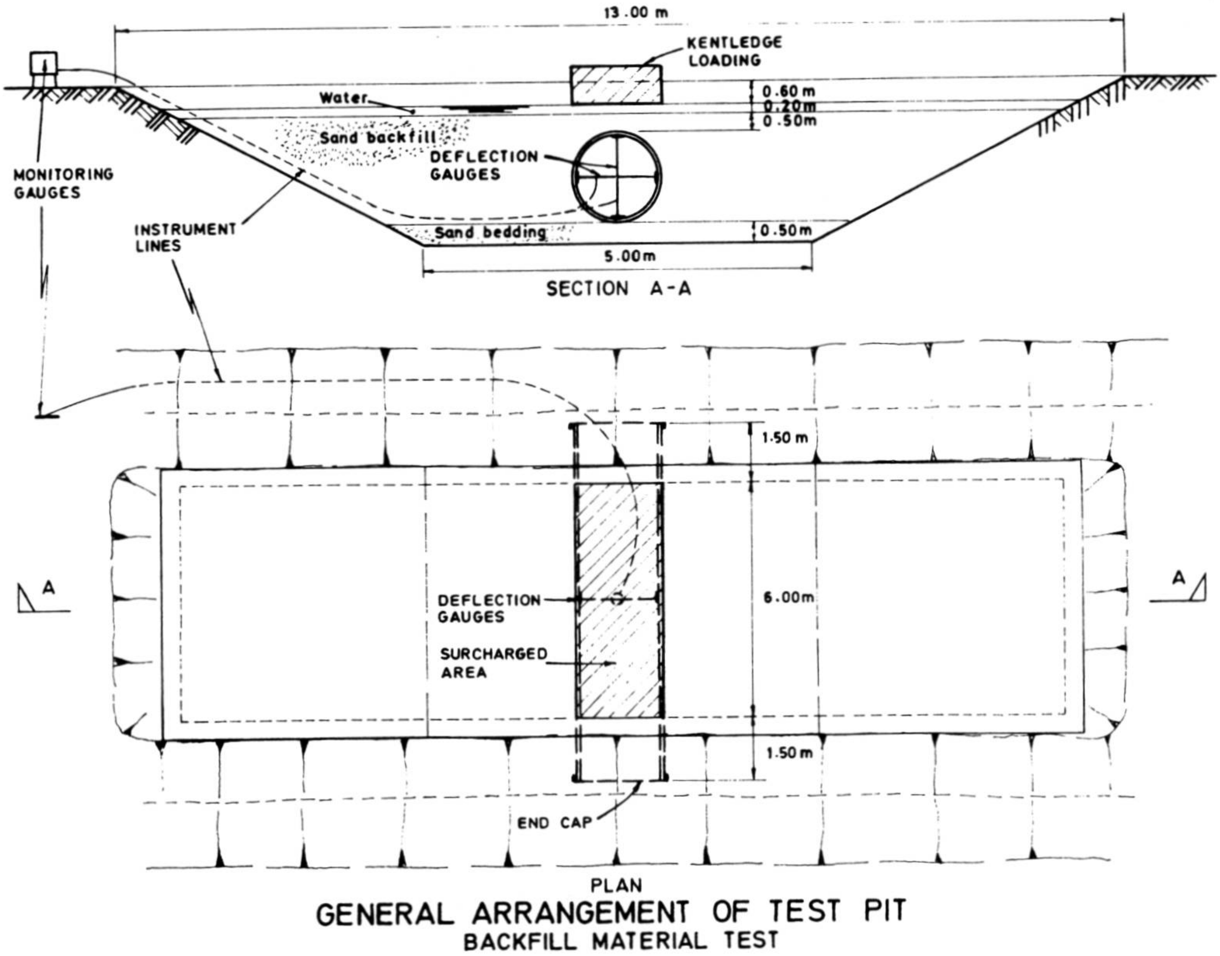

Fig. 3 Pipe support details for test

Consideration was given to the use of two or three smaller pipes with the options of phasing the outfall capacity. However nett present value calculations indicated that a single 2.0 m diameter pipe could be the cheapest solution although the resulting velocity through the pipe during the earliest stages of development would be rather low. Fig. 2 shows the longitudinal section of the final scheme showing the 10 vertical risers at the offshore end; each having two ports of 300 mm diameter. Under favourable conditions the sewage is diluted by a factor of approximately 300 immediately adjacent to the outlet.

Pipeline

The option of tunnelling was ruled out once the site investigation had revealed inconsistent clays and bands forming the estuary bed in the marine section.

The 2.0 m diameter pipe line was therefore to be pulled into a predredged trench by a winch anchored in the middle of the estuary. The pipe has a minimum of 2.0 m cover below the estuary bed to protect against anchors and also to allow for scouring and bed movement. The gradient of the outfall was required to be not flatter than 1 in 1000 falling towards the offshore end.

Protection

Preliminary investigations had shown that the pipe may have to take effluents with a PH range of 1-10 and up to temperatures of 35°C. To achieve the 100 year design life GRP was chosen as the internal lining. The pipe was manufactured with a stiffness of 1 100 N/m^2 and a thickness of 24 mm to BS 5480. A special internal gel coat of 2 mm thick Vinyl Ester Resin was specified to meet the corrosive environment. The design of the composite pipe was calculated to limit the internal strain on the GRP pipe by not allowing a deflection of more than 2 % in the short term. The bending radius during construction was limited to 100 m.

The steel pipe was protected externally by a bitumen enamel coating which was reinforced with layers of glass fibre. Further protection and stiffness was provided by the concrete weight coat which was reinforced with mesh reinforcement and provided both, mechanical protection against damage to the coating during pulling, and against possible future anchor impact.

In addition the steel pipe is protected by an impressed current cathodic protection system.

Pipe design

The main structural element of the composite outfall pipe is the steel pipe which was constructed from 2.24 m diameter pipes manufactured by three different companies. Those produced by the spiral wound process were found to be easier to use than the longitudinally welded pipes due to their superior roundness. The pipes were butt welded together in accordance with BS 4515. Four welders were able to work on any one joint at once. All joints were radiographed to check the welding quality.

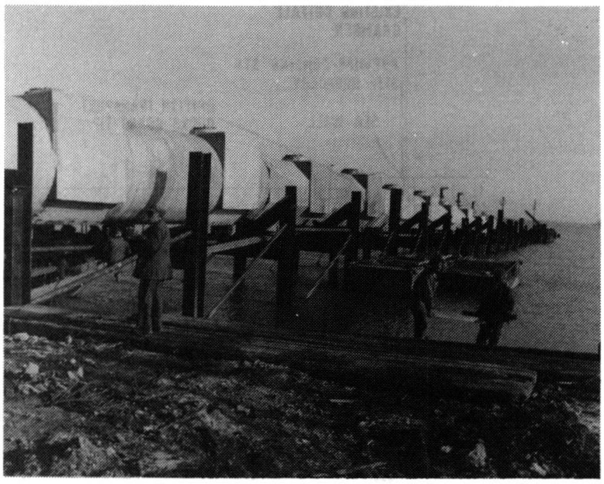

Fig. 4 Photograph showing pipe and launch ramp

The worst loading condition on the pipeline occurs at approximately 2500 m offshore were the pipe passes through Bureom sands and is backfilled to a depth of 3.8 m. Adjacent to this deepest section, the pipe is also passing through a vertical curve and therefore the combined stresses had to be analysed. To prevent the thin wall pipe buckling the support of the backfill has to be utilized. A value for the modulus of passive resistance E′ of 3 MN/m^2 was required. As there was no means readily available to determine the modulus for the dredged river gravel to be used as bedding and backfill a full scale trial was set up (Fig. 3). By adjusting the kentledge different surcharge load conditions could be investigated. The results demonstrated that the fine aggregate available would provide the modulus required when placed under water. In practice the composite pipe was considerably stiffer than any of the individual component parts. So much so that this did cause some difficulty for the contractor in pulling the pipe down the reverse curve of the launch ramp (Fig. 4).

Construction

The steel pipes used were welded together into 10 No 250 m long strings. The concrete surround was placed using external shutters while the GRP pipes were slid into the steel pipe and jointed using sleeve type push fit connections. Concrete space blocks were affixed to the external crown of the GRP pipes so that when the liquid PFA grout was pumped in the pipe floated up to a concentric position.

When the first string with the diffusers had been pulled out the next 250 m length was rolled in behind it; the steel pipe welded up and a special GRP make-up piece inserted to ensure continuity of all linings. A similar process was repeated until the full length had been pulled into the dredged trench. The pipe was the backfilled and then original estuary bed level re-established.

The concrete diffusers were constructed in precast concrete sections to facilitate the removal or addition of modules to adjust to changing bed levels. The concrete units were protected by the application of a thick epoxy cold applied coating.

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