UNIVERSITAS
GADJAH MADA
**Analisis Distribusi Tegangan dan Deformasi pada Pipa Corrugated Steel Pipe Akibat Kekakuan Manhole
dan Penurunan Tanah Studi Kasus Line Outfall Condensor PLTU.**
Dimas Aditya Putra, Dr. Eng. Ir. Fikri Faris, S.T., M.Eng., IPM.
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

INTISARI

Saluran *outfall* kondensor merupakan sistem penyalur air pendingin sisa proses kondensasi uap pada kondensor PLTU untuk dialirkan kembali ke laut. Pada PLTU Tarahan, Lampung, saluran ini dibangun menggunakan pipa *Corrugated Steel Pipe* (CSP) yang bersifat fleksibel dan telah beroperasi sejak tahun 2007, sehingga saat ini pipa telah memikul beban operasional selama hampir dua dekade dan terhubung dengan manhole beton bertulang yang kaku. Perbedaan kekakuan yang besar antara pipa fleksibel dan manhole kaku, dikombinasikan dengan penurunan tanah pada lapisan lempung lunak pesisir serta penipisan dinding pipa akibat korosi, berpotensi menimbulkan konsentrasi tegangan pada zona sambungan pipa–manhole. Indikasi awal permasalahan ini diperkuat oleh teramatinya *sinkhole* pada segmen MH3 dan MH6 dua manhole yang mengapit segmen MH4–MH5 pada saluran *outfall* yang sama sementara perilaku tegangan pada MH4–MH5 belum pernah dianalisis secara simultan. Penelitian ini bertujuan menganalisis distribusi tegangan dan deformasi pipa CSP pada segmen MH4–MH5 akibat kekakuan manhole eksisting dan penurunan tanah, serta mengidentifikasi kondisi kritis pada sistem sambungan tersebut.

Studi kasus difokuskan pada segmen MH4–MH5 saluran *outfall* kondensor PLTU Tarahan, Lampung. Data yang digunakan meliputi parameter tanah hasil penyelidikan lapangan dan laboratorium, geometri serta properti material pipa CSP dan manhole, dan data korosi hasil inspeksi lapangan. Analisis dilakukan menggunakan pemodelan numerik berbasis metode elemen hingga dengan perangkat lunak PLAXIS 2D pada kondisi regangan bidang (*plane strain*), dengan pipa CSP dimodelkan sebagai elemen solid ekuivalen. Tahapan pembebanan disimulasikan melalui *staged construction* yang mencakup fase tegangan awal (K_0), instalasi, konsolidasi, dan operasional. Poin yang dibahas mencakup distribusi tegangan normal dan geser pada dinding pipa, deformasi dan pola penurunan tanah, serta evaluasi keamanan struktur melalui faktor keamanan geser dan kompresi cincin (*ring compression*).

Hasil analisis menunjukkan distribusi tegangan yang sangat tidak seragam. Tegangan tekan ekstrem terjadi di *crown* sambungan hingga −529,287 kN/m² dan berbalik menjadi tegangan tarik di *invert* hingga +284,713 kN/m², tegangan normal aktual terkonversi mencapai 80,8% dari kuat leleh baja pada *crown* sambungan. Kekakuan manhole menjadi pengendali dominan penurunan diferensial dengan kontribusi 97,7% sedangkan konsolidasi tanah hanya menyumbang 2,3%. Faktor keamanan geser yang tersedia tetap aman dengan SF_{geser} 5,15, demikian pula kompresi cincin pada kondisi terkorosi dengan SF = 4,41. Dengan demikian, kondisi kritis sistem tidak bersumber dari keterlampauan kapasitas struktur, melainkan dari konsentrasi tegangan lokal pada sambungan yang diperberat korosi pada zona tarik, yang secara dominan dikendalikan oleh kekakuan manhole dan bukan oleh penurunan tanah. Berdasarkan temuan tersebut, upaya penanganan direkomendasikan diarahkan pada pengendalian dan pemantauan korosi di zona sambungan pipa–manhole, khususnya pada bagian *invert* yang mengalami tegangan tarik, bukan pada mitigasi penurunan tanah.

Kata kunci : *Corrugated Steel Pipe,* Distribusi Tegangan, Kekakuan Manhole, Penurunan Tanah

UNIVERSITAS
GADJAH MADA
**Analisis Distribusi Tegangan dan Deformasi pada Pipa Corrugated Steel Pipe Akibat Kekakuan Manhole
dan Penurunan Tanah Studi Kasus Line Outfall Condensor PLTU.**
Dimas Aditya Putra, Dr. Eng. Ir. Fikri Faris, S.T., M.Eng., IPM.
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

ABSTRACT

A condenser outfall channel is a system that conveys residual cooling water from the steam condensation process in a power plant condenser back to the sea. At the Tarahan Steam Power Plant (PLTU Tarahan), Lampung, this channel was constructed using flexible Corrugated Steel Pipe (CSP), which has been in operation since 2007 and has therefore borne operational loads for nearly two decades, and is connected to rigid reinforced-concrete manholes. The substantial stiffness difference between the flexible pipe and the rigid manholes, combined with ground settlement in the soft coastal clay layer and wall thinning due to corrosion, is likely to induce stress concentration at the pipe–manhole junction. Early indications of this problem are reinforced by the observation of sinkholes at segments MH3 and MH6 the two manholes flanking segment MH4–MH5 along the same outfall channel while the stress behavior at MH4–MH5 has never been analyzed simultaneously. This study aims to analyze the stress distribution and deformation of the CSP at segment MH4–MH5 due to the stiffness of the existing manholes and ground settlement, and to identify the critical conditions of the junction system.

The case study focuses on segment MH4–MH5 of the condenser outfall channel at PLTU Tarahan, Lampung. The data used comprise soil parameters obtained from field and laboratory investigations, the geometry and material properties of the CSP and manholes, and corrosion data from field inspections. The analysis was carried out using finite element numerical modeling with PLAXIS 2D software under plane-strain conditions, in which the CSP was modeled as an equivalent solid element. The loading stages were simulated through a staged construction procedure comprising the initial stress (K_0), installation, consolidation, and operational phases. The aspects examined include the distribution of normal and shear stresses along the pipe wall, deformation and ground settlement patterns, and the structural safety evaluation based on the shear safety factor and ring compression.

The analysis results reveal a highly non-uniform stress distribution. Extreme compressive stress occurs at the crown of the junction, reaching −529.287 kN/m², and reverses into tensile stress at the invert, reaching +284.713 kN/m²; the converted actual normal stress reaches 80.8% of the steel yield strength at the crown of the junction. Manhole stiffness is the dominant controlling factor of differential settlement, contributing 97.7%, whereas soil consolidation accounts for only 2.3%. The available shear safety factor remains safe, with SF_shear = 5.15, as does the ring compression under the corroded condition, with SF = 4.41. Accordingly, the critical condition of the system does not stem from the exceedance of structural capacity, but rather from localized stress concentration at the junction, aggravated by corrosion in the tensile zone, and predominantly governed by manhole stiffness rather than by ground settlement. Based on these findings, remedial efforts are recommended to be directed toward controlling and monitoring corrosion at the pipe–manhole junction, particularly at the invert subjected to tensile stress, rather than toward ground settlement mitigation.

Keywords: Corrugated Steel Pipe, Stress Distribution, Manhole Stiffness, ground settlement