Shallow covered waste-water conduits

Test apparatus for minimum soil cover of conduits

Shallow conduit coverings are of particular interest since, on the one hand, such applications are increasing and, on the other hand, the pipes are exposed to high soil stresses resulting from live traffic loads. In a recently completed research project [1], 1:1 scale tests and FEM simulations were used to determine the load situations for the pipe under various depths of cover.

Transverse earth pressure from live traffic loads

Since 1984, static calculation of soil-buried waste-water lines and conduits has been performed in accordance with ATV-DVWK code A 127 [2]. Two options for „European pipe statics" were, it is true, drafted within the framework of CEN/TC165/WG12, but no agreement on a finalized procedure was reached. The DWA ES 5.5 workgroup is therefore preparing a 4th edition of the A 127 code, in order to take into account further developments in pipe production and installation, and the necessity of conforming to customary European provisions concerning stability. It will also be possible in this context to incorporate more recent know ledge concerning the load-bearing mechanism of the pipe/soil system.

These investigations are also intended to supply information on the residual stability of damaged pipes and on calculation of repair systems for existing pipes no longer capable of bearing the relevant loads alone. Typical loads acting on shallow covered conduits take the form of vertical loads exerted on the pipe crown with only slight transverse reinforcement from earth pressure, longitudinal load-bearing by the pipes from concentrated surface loads, and load concentrations at the pipe crown (load bridge), see [3].

The horizontal support force resulting from wheel loads on the surface are firstly to be examined in more detail; when Cover h is kept constant in accordance with Figure 1 and external pipe diameter is enlarged, the vertical stresses adjacent to the side zones of the pipe decrease. A geometrical criterion including the values h, da and a therefore applies for the reinforcing transverse pressure. The tests performed provide measured data sufficient for verification of the equations. In the case of flexible pipes, the lateral reaction pressure and bedding reaction pressure are measured together, and these tests are therefore performed on a rigid pipe material.

Live traffic loads in accordance with DIN Technical Report 101

The magnitude and distribution of the loads resulting from the twin axles of the two heavy-goods vehicles can be seen in Figure 2. Unlike the previous provision, tire contact areas of 40 x 40 cm², inter alia, are included, the wheelbase has been reduced, the total load of the vehicles is now 4 x F_1 = 480 and 320 kN (previously 6 x F_1 = 600 and 300 kN) and the impact factor is now included (previously: 1.2 for HGV 60 and 1.5 for Truck 12).

In view of the increase in heavy-goods traffic (see the traffic forecasts published by the Federal Ministry of Transport, Building and Urban Affairs [BMVBS] for 2015 [4]) – intense two-way traffic must also be anticipated within built-up areas. The effects of overtaking vehicles on pipes were investigated by Hornung for the previous DIN 1072 standard, see [5].

Tests were performed both with a 60 cm clearance for 3 m wide traffic lanes (NL = „normal load position") and for narrow wheel positions (EL). According to DIN Technical Report 101 [6], traffic lanes widths of 2.7 m are possible with unobstructed wheel spacings of 10 cm, see Figure 2, but it was possible, for technical reasons, to reduce the spacing only to 25 cm. An approx. 1.4-fold increase in load compared to NL was measured in this context.

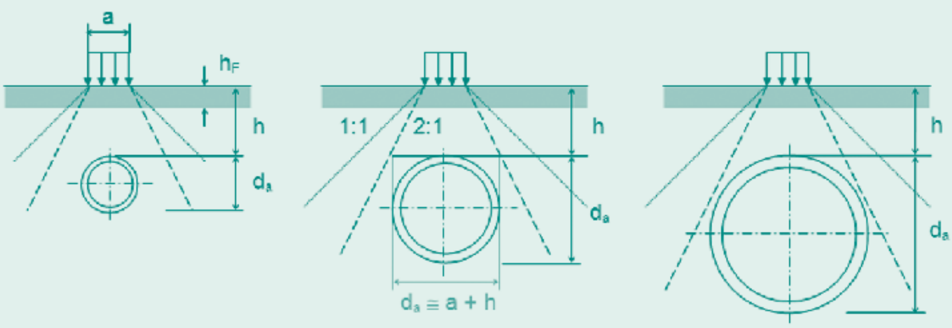


Figure 1: Stress distribution of partial surface load in the soil for constant cover depth and various nominal diameters (diagram in principle)

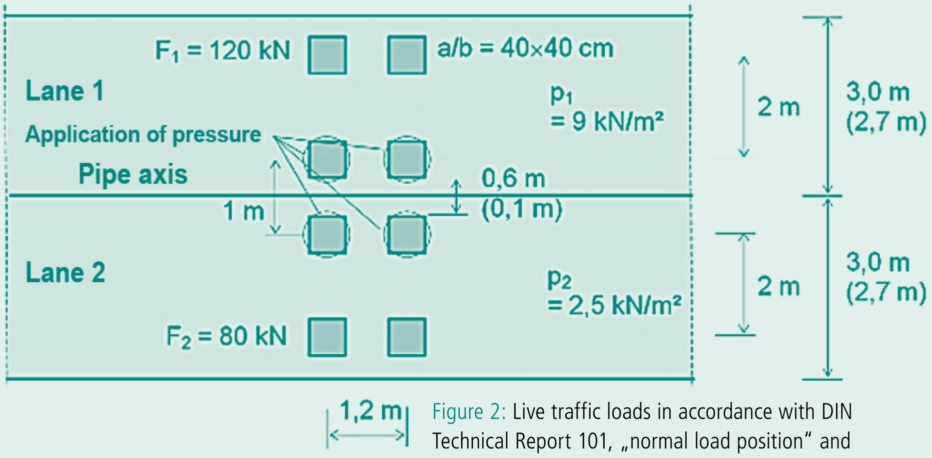


Figure 2: Live traffic loads in accordance with DIN Technical Report 101, „normal load position" and arrangement of presses for the load tests

Figure 3: Installation of profiled polyethylene pipes, structure of pipe wall

Further investigation targets

The tests on shallowly covered pipes consisting of concrete, ductile cast iron and polyethylene were intended to examine not only the magnitude of the transverse earth pressure, but also the following topical questions:

- What effects do the live traffic loads in accordance with DIN Technical Report 101 have, and what is the effect of overtaking HGVs in case of close passing?
- Where is the definitive proof point (pipe crown or pipe sole)?
- What influence does the carriageway surfacing have?
- What happens at and around the carriageway edges, and points of carriageway damage?
- What different load-bearing actions do rigid, flexible and profiled pipes have in the longitudinal direction?
- How should the stability of damaged pipes be assessed?

The aim is, in addition, calibration of an FEM model for the purpose of investigation of further load cases and installation situations.

Test apparatus at the IKT large-scale test facility

ND 700 pipe strings consisting of various pipe materials were installed at the IKT large-scale test facility. In addition to concrete pipes with a base, ductile cast-iron pipes of pressure level PN6 which, to permit the application of strain gauges, had no internal cement-mortar lining and no external corrosion-protection system, were also used. In addition, a further pipe string consisting of profiled PE pipes was installed after removal of the cast-iron pipe string, see Figure 3.

Soil

A sand/gravel mixture with a particle-size of 0/8 mm (Rhine sand) was used as the soil material. Rhine sand is consistently delivered by a supplier from a selected sand/gravel pit, signifying that the soil installed in the test facility exhibited virtually the same material properties at all levels. The soil was installed in accordance with the requirements of ATV-DVWK code A 139 [7], taking account of Compressibility Class V1, with compaction tests performed by the Leibniz University of Hanover; a mean degree of compaction of 95% Proctor density was determined here.

The selection of the soil material, and soil and pipe installation with careful gusset compaction, creates a typical situation for installation of pipes with shallow cover under roadways.

Diverging installation cases are to be examined by means of a Finite Element model and the reduction factors provided in ATV code A 127.

Pipes and manhole-shafts

A pipe string was installed in the longitudinal direction of the test facility for every pipe material, see Figure 4. The cast-iron and concrete pipe strings consisted in each case of six pipes and a starting, center and end manhole-shaft. In addition, a plastic pipe string consisting of three pipes and a starting and end shaft was also installed. The constructions between the manhole-shafts consist of a long center section and two short flexibly jointed elements.

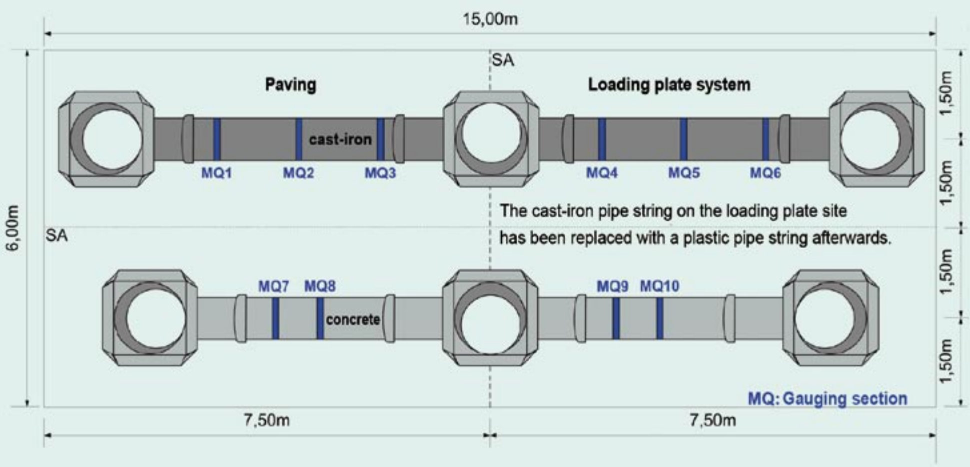


Figure 4: Basic test structure at the IKT large-scale test facility

Road pavement

A paved surface was selected as the road pavement for the cast-iron and concrete pipe strings, and for all pipe materials, a steel-plate structure, which made it possible to simulate various road pavements. Both road pavements were designed for a cover of approx. 80 cm above the pipe crown.

Paved surface

On the basis on [8], a surface consisting of rectangular concrete paving stones of Construction Class III in accordance with RStO 01 [Ordinance on highway structure, see 9] was selected as a representative paved surface. The paved surface was installed across the entire width in one half of the large-scale test facility, between the starting and center shaft of the cast-iron and concrete pipe strings. The paving work was performed by a specialist company in accordance with „TL Pflaster-StB 06" [official code for performance of road paving work, see 10]. The rectangular concrete paving stone selected, of dimensions 20 x 10 x 10 cm, was installed on a surface of around 24 m² in stretcher bond, on a gravel/sand layer of 42 cm, a gravel sub-base course of 25 cm and a 3 cm thick paving bed consisting of crushed rock. The side rows of paving was set in a mortar bed of Strength Class C12/15, and the joints then completely grouted.

Load-plate structure

A load-plate structure was selected for the other half of the large-scale test facility, in order to permit simulation of various road pavement types. The structure, consisting of one or of two steel plates, was used to generate stress states on the subgrade corresponding to those found in real carriageway surfaces consisting of bitumen and concrete. The equivalent stress values at the subgrade level were determined at the Department of Highway Engineering of the Ruhr University, Bochum, for various construction classes and carriageway surfaces, and used for specification of plate dimensions [8]. Mathematical cover depths including road pavement of 80 and 88 cm result for installation of the gravel/sand mixture up to 66 cm above the pipe crown and the use of one or two steel plates.

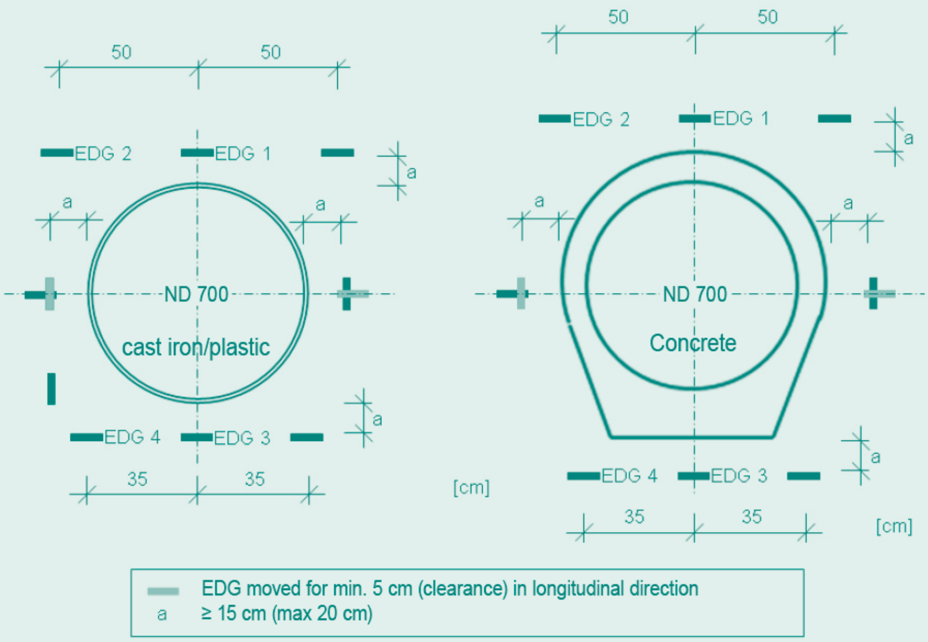


Figure 6: Location of the earth pressure transducers in the main gauging sections

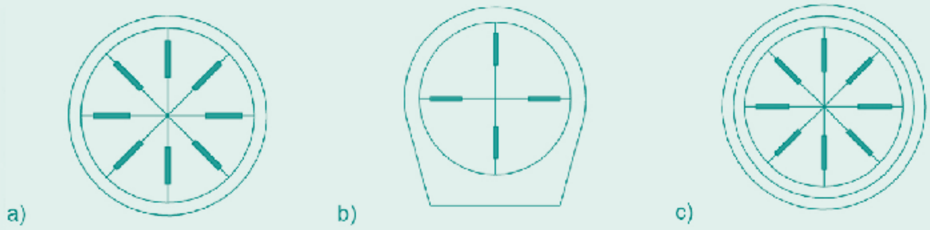


Figure 7: Location of position transducers in the main gauging sections in the a) cast-iron, b) concrete and c) plastic pipe string (measurement in the horizontal and vertical directions only at the subsidiary gauging sections)

Measuring system

Several gauging sections featuring sensors for measurement of significant soil and pipe stresses, and also pipe deformations and movements, were set up in the pipe strings shown in Figure 4. The main gauging sections MQ2, MQ5, MQ8, MQ10 and MQ12 were located at the center point of the center pipes of the pipe constructions, viewed in the longitudinal direction of the pipes. Subsidiary gauging sections MQ1, MQ3, MQ4 and MQ6 in the cast-iron pipe string, MQ7 and MQ9 in the concrete pipe string, and MQ11 and MQ13 in the plastic pipe string were positioned at the tapered end or on the socket in the boundary zones of the measuring pipes.

The main gauging sections were equipped with strain gauges, earth pressure transducers and position transducers. Figures 5 to 7 show the number and positioning of the measuring equipment described above in the main gauging sections of the cast-iron, concrete and plastic pipe strings.

Due to the profiling of its external surface, strain gauges were installed only on the inner side of the pipe in the case of the plastic pipe string. In

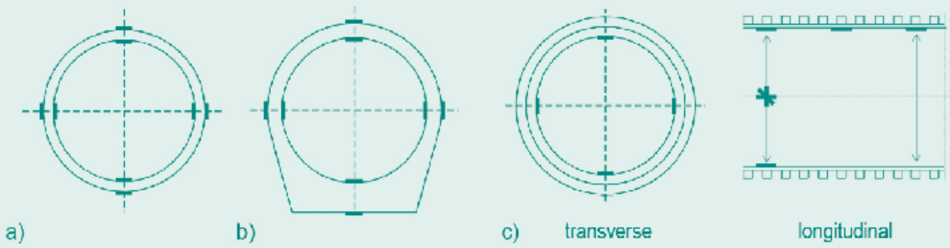


Figure 5: Location of strain gauges (axial, radial and diagonal in each case) in the main gauging sections in the a) cast-iron, b) concrete and c) plastic pipe string

addition, further strain gauges were applied in the longitudinal direction of the pipe crown, see Figure 5c. Position transducers were installed in all the subsidiary gauging sections, and pressure-measurement films on the outer side in MQ1 and MQ6 in the cast-iron pipe string, in addition.

Eight position transducers were installed in the main gauging sections of the cast-iron and plastic pipe strings, and four position transducers in all other gauging sections, see Figure 7. The position transducers were installed on aluminium measuring bridges, which were fixed in the adjacent manhole-shafts, see Figure 8.

Performance of tests

Static and load-cycle tests were performed on the test apparatus described above and the dimensioning-relevant variables measured and recorded, in order to determine the behaviour of shallowly covered pipes under live traffic loads:

- Load case: Single wheel, static
- Load case: Single wheel, load-cycles
- Load case: Wheel group, static
- Load case: Installation state
- Load case: Edge pressure
- Supplementary tests

Round 30 mm thick steel plates of a diameter of 0.44 m, bearing rubber pads, were installed under the hydraulic presses.

Load case: Single wheel, static

For the „Single wheel, static" (Z) load case, a single hydraulic cylinder was positioned centrally over the respective main gauging sections of the three pipe strings. Two load plates were laid one on the other over the cast-iron and concrete pipe strings in order to simulate a carriageway pavement of approx. 22 cm. One steel plate is equivalent to an asphalt thickness of 14 cm. The „Single-wheel, static" load case was investigated on the plastic pipe string both with one and with two load plates. In each individual test on the paved and the load-plate side, three different load levels of 60 kN, 90 kN and 120 kN were set, and maintained for a period of 30 minutes.

Load case: Single wheel, load-cycles

The „Single wheel, load-cycles" (D) tests were performed with a hydraulic cylinder on the paved and the load-plate side above the

Figure 8: Installation of position transducer assembly
above: Installation of a measuring bloc on the measuring bridge
below: Positioning of a measuring bloc in the pipe

cast-iron and the concrete pipe string; no cyclical loads were applied above the plastic pipe string. The hydraulic cylinder and load plates were arranged for this purpose in the same way as in the „Single-wheel, static" load case, i.e., centrally above the appurtenant main gauging sections. The load-cycle tests were performed to 106 load cycles at a frequency of 3 Hz, for a test period of around four days in each case. 90 kN and 20 kN were adjusted as the maximum and minimum loads.

Load case: wheel group, static

The „Wheel group, static" tests were performed using four hydraulic cylinders on the paved and load-plate side above the cast-iron and the concrete pipe string and above the plastic pipe string, see Figure 9. In these tests, the four hydraulic cylinders simulate the static wheel loads generated by a twin axle in accordance with DIN Technical Report 101. The four possible load positions of „normal „ (NL), „eccentric" (XL), „narrow longitudinal" (ELL) and „narrow transverse" (ELQ) were investigated for simulation of differing load situations. The load positions differed in the spacing of the wheel loads in the longitudinal and transverse direction and in the number of cylinders used. The wheel-load

Figure 9: Load transmission for the „Wheel group, static" load case

spacings were specified with reference to DIN Technical Report 101 [6], see Figure 10.

As previously, three different load magnitudes of 60 kN, 90 kN and 120 kN, were adjusted for all load positions and maintained for a period of 30 minutes. In order to vary the road pavement, the tests were performed in a number of cases both with one and with two stacked steel plates on the loading-plate side. In addition, selected load positions of the „Wheel group, static" load case were also investigated on the loading-plate side for two shallower cover depths of h = 68 /h = 60 cm and h = 48 cm/h = 40 cm above the cast-iron and the concrete pipe strings.

Load case: Installation state

For simulation of pipe loading in installation states, the paving on the paved side, and/or the loading plates, were removed and static forces transmitted into the soil by means of a single cylinder. The hydraulic cylinder was positioned centrally above the main gauging sections of the pipe string. A round steel plate of 830 mm diameter and 115 mm thickness was used for load transmission. Forces of 60 kN, 90 kN and 120 kN were again transmitted into the soil and maintained for a period of 30 minutes.

Load case: Edge pressure

The load case: Edge pressure (KP) was examined for the cast-iron and concrete pipe strings for Cover h = 40 cm, and for the plastic pipe string, see the „Damaged carriageway surface" section. Unlike the preceding tests for the „Wheel group, static" load case, here two hydraulic cylinders located 700 mm apart in the longitudinal direc-

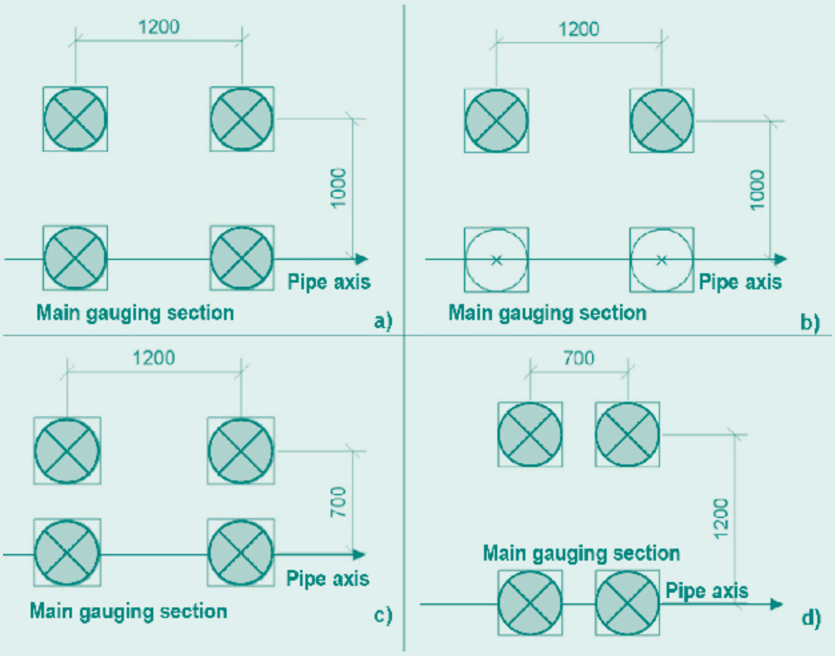


Figure 10: Load positions for the „Wheel group, static" load case:
a) NL = normal, b) XL = eccentric, c) ELL = narrow longitudinal, d) ELQ = narrow transverse

tion of the pipes were used. A steel plate was positioned for this purpose in the transverse direction above each pipe string in such a way that the load-transmission structure consisting of a rubber mat and a steel plate was flush with the edge of the plate above the main gauging section.

Further tests on the plastic pipe string

Supplementary static tests for a period of 40 hours, and also tests with sudden application of the load, were performed, in order also to obtain information on creep behaviour and behaviour under dynamic loads.

In order to verify the indication accuracy of the strain gauges used, additional vertical compression tests were performed on sections consisting of all the pipe materials after removal of the pipe strings from the large-scale test facility.

Evaluation of test results

Pipe stresses

Figure 11 shows by way of example the crown and sole stresses for the cast-iron pipe throughout the entire test period; it is apparent that the stresses do not decline to zero after each load-application/load removal test cycle, but instead continue to rise. This can be explained by soil-mechanical effects, such as trapping between the soil and the pipe surface resulting from the application of load, for example.

According to ATV-DVWK code A 127 [2], the pipe sole is in all cases definitive in calculations for a sand/gravel bed with an angle of repose of $2\alpha < 180°$. In shallowly covered pipes, however, the pipe crown is subjected throughout the test duration to significantly higher loadings than the sole, see Figure 11. Maximum pipe stresses occur in the „edge pressure" load case.

Influence of transverse traffic-induced earth pressure

The supporting transverse traffic-induced earth pressure $q_h(p_V)$ acting in the side zone is taken into account in various European standards, but not, up to now, in ATV code A 127 [2]. This transverse pressure can be estimated using the following equations:

Case 1: $(h + 0{,}4) / d_a \geq 1 \longrightarrow q_h(p_V) = 0$ (1a)
Case 2: $(h + 0{,}4) / d_a \geq 2 \longrightarrow q_h(p_V) = K_2 \cdot p_{V,K}$ (1b)
in which $p_{V,K}$ = vertical traffic-induced soil stress adjacent to pipe side zones

Intermediate values are linearly interpolated:
$q_h(p_V) = K_2 \cdot p_{V,K} \cdot f$ in which $f = (h + 0{,}4 - d_a) / d_a$ (1c)

The limiting case in Equation (1a) is defined by the fact that radiation of the quadratic wheel load reaches the outer diameter of the pipe at side length a = 0.4 m in the pipe crown, see Figure 1, center view.

In Table 1, vertical soil stress $p_{V,K}$ at the level of Side Zone K_1 is determined, in accordance with Figure 12, using the load distribution model. Horizontal soil stress $q_h(p_V)$ is then calculated using coefficient of earth pressure $K_2 = 0.4$ for non-cohesive soil, see Table 2.

The horizontal soil stresses $\sigma_{h,K}$ measured in the test are above the values determined in accordance with Equations (1a-c), i.e., the assumption for traffic-induced transverse earth pressure is on the safe side. Transverse earth pressures were, in fact, still measured in the IKT large-scale test facility at minimum cover, corresponding to Case 1 in accordance with Equation (1a).

The influence of carriageway surfacing

Undamaged carriageway surfacing

Carriageway surfaces in the form of asphalt decks of Construction Classes III and V as per RstO 01 [9] were simulated by means of one steel plate of dimensions 3.4 m x 3.0 m, and by means of two steel plates of dimensions 3.4 m x 3.0 m and 3.0 m x 2.0 m, with a thickness, in each case, of 30 mm. A reduction in vertical earth pressure compared to the calculated values was observed above both the concrete and cast-iron pipes. This decrease was larger in the case of the flexible cast-iron pipes than in the case of the concrete pipe.

The test with a paved surface indicated the greatest soil stresses, a fact which can be attributed to the low bonding of the paving stones and the absence of any load distribution by the paving. Calculated cover depth h should therefore be reduced by the thickness of the paved layer for calculation of p_V.

During installation, a layer of gravel ballast is frequently laid over the pipe, and there is, in some cases, a total lack of surfacing of the site access routes. The appurtenant loading tests without steel plates also resulted in higher measured data.

Damaged carriageway surfaces

Hydraulic cylinders (pressure-application cylinders) were positioned, as a special case, extremely close to the edge of the steel plate in the IKT large-scale test facility (the „edge pressure" load case). This, in practice, makes it possible to simulate, for instance, the transition

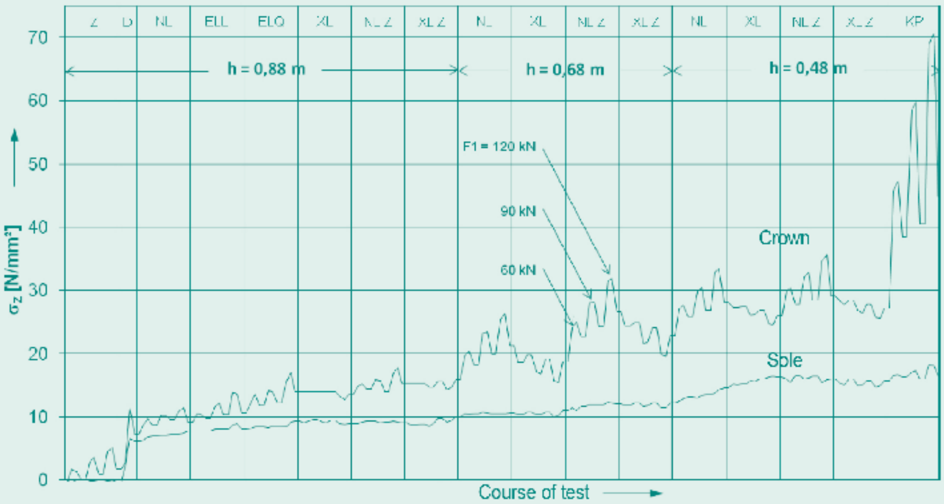


Figure 11: Circumferential stresses in the ductile cast-iron ND 700 pipe at various cover depths h, Test sequence: NL = normal load position (see Figure 2), Z = central, D = load-cycles (N = 10^6), ELL = narrow longitudinal passage, ELQ = narrow transverse passage, XL = eccentric, KP = edge pressure, Addition Z: Construction Class V as per [9] (one steel plate)

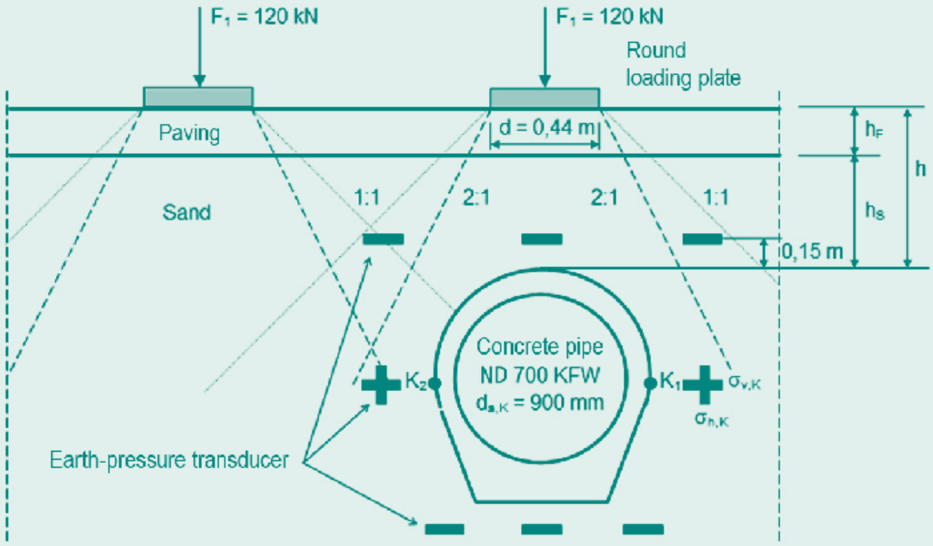


Figure 12: Spread of load over the ND 700 concrete pipe KFW, normal load position (to scale for h = 0.88 m)

Table 1: Vertical soil stress in the side zone of the concrete pipe, d_a = 0.93 m

h	$h_K = h + 0.465$	$b_m = l_m = h_K + 0.4$	$A_m = b_m \cdot lm$	$p_{V,K} = F_1/A_m$
m	m	m	m²	kN/m²
0.88	1.345	1.745	3.04	39.5
0.68	1.145	1.545	2.39	50.2
0.48	0.945	1.345	1.81	66.3

Table 2: Horizontal soil stresses in the side zone of the concrete pipe, d_a = 0.93 m

h	Eq. (1a): $(h + 0.4)/d_a$	Eq. (1c): f	Tab. 1: $p_{V,K}$	Eq. (1c): $q_h(p_V) = K_2 \cdot p_{V,K} \cdot f$	Measured value $\sigma_{v,K}$	Measured value $\sigma_{h,K}$
m	-	-	kN/m²	kN/m²	kN/m²	kN/m²
0.88	1.38 > 1	0.376	39.5	**5.94**	13.7	**6.0**
0.68	1.16 > 1	0.161	50.2	**3.23**	16.3	**4.7**
0.48	0.95 < 1	0	66.3	**0**	16.5	**7.0**

zone from concrete-surfaced carriageways to other carriageway surface types, or a transverse crack in the road surface, see Figure 13. Here, the live traffic loads are no longer transmitted uniformly into the subgrade but, instead, approximately triangularly, see Figure 14.

The „edge pressure" load case results in significantly greater soil stresses and pipe stresses compared to the normal load position in accordance with DIN Technical Report 101 [6]. The soil stresses above the crown of the concrete pipe are greater by a factor of 2.9 compared to the normal load position. This factor is, in fact, 4.2 over the cast-iron pipe. A considerably increased load on buried pipes must therefore be anticipated in case of damaged road surfaces and in the vicinity of transitions in carriageway surfaces, if no provision to assure transmission of transverse forces is implemented.

Longitudinal load-bearing action of pipes

Figure 15 shows the changes in diameter of the two flexible pipes for normal load position in accordance with DIN Technical Report 101. The deformations of the profiled wound PE pipe have a lesser extent in the longitudinal direction of the pipe than those in the ductile cast-iron pipe. This can be explained by the load-bearing action as an orthotropic shell, which takes place primarily in the circumferential direction.

The deformations in the longitudinal direction also include longitudinal stresses, however, which are generally not taken into account in pipe-statics calculations. The aim of this research project is, therefore, also the development of a simple, calibrated computation model of three-dimensional load-bearing action, e.g., the flexibly bedded beam.

Load transmission in the longitudinal direction is not possible in the case of short pipes and pipes

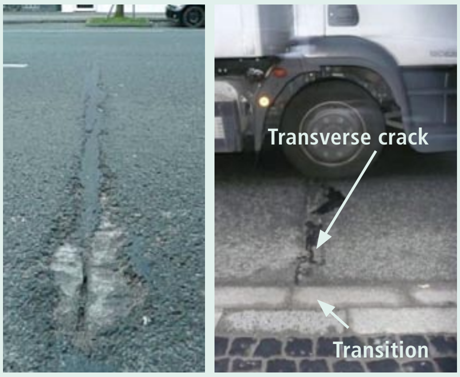


Figure 13: The „edge pressure“ (KP) load case with a transverse crack in the road surface, transition between various carriageway structures

with transverse cracks. An increase in the live traffic loads is necessary in such cases.

Calibration of the FEM model

A three-dimensional Finite Element model is generated using the ABAQUS program to permit comparative assessment of numerical models against the test results and for investigation of further load cases, see Figure 16, with cross-linking and pipe stresses.

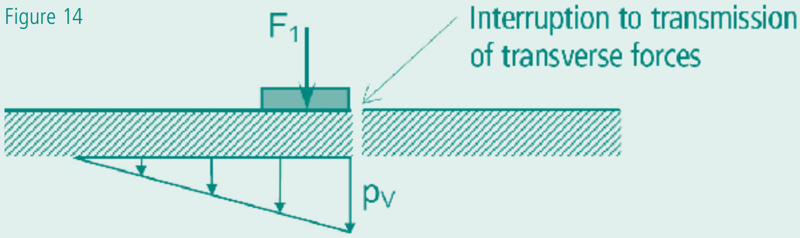
A linear-elastic materials law suffices for simulation of the asphalt surface course in the case of the steel plates, while computations using an elastic and, additionally, a plastic law in accordance with Mohr-Coulomb are performed for the soil. Transmission of tensile stresses between the steel plate and the soil and between the soil and the pipe is prevented by means of contact elements. Symmetry conditions are assumed for modeling, see Figure 16.

The calculations in accordance with the A 127 code and the FE model supply significantly higher pipe stresses for h = 0.88 m than the data measured for normal load position in the IKT large-scale test facility, see Figure 7. The edge pressure load case is also included as the „worst case“, the transmitted pipe stresses σ_φ apply in case of a shallower cover (h = 0.40 m) and Construction Class V, however.

Summary

Tests on buried concrete, cast-iron and PE pipes embedded at a shallow depth, with load configurations in accordance with DIN Technical Report 101 [6] are reported. The soil stresses in the vicinity of the pipe, the pipe stresses in the

Figure 14



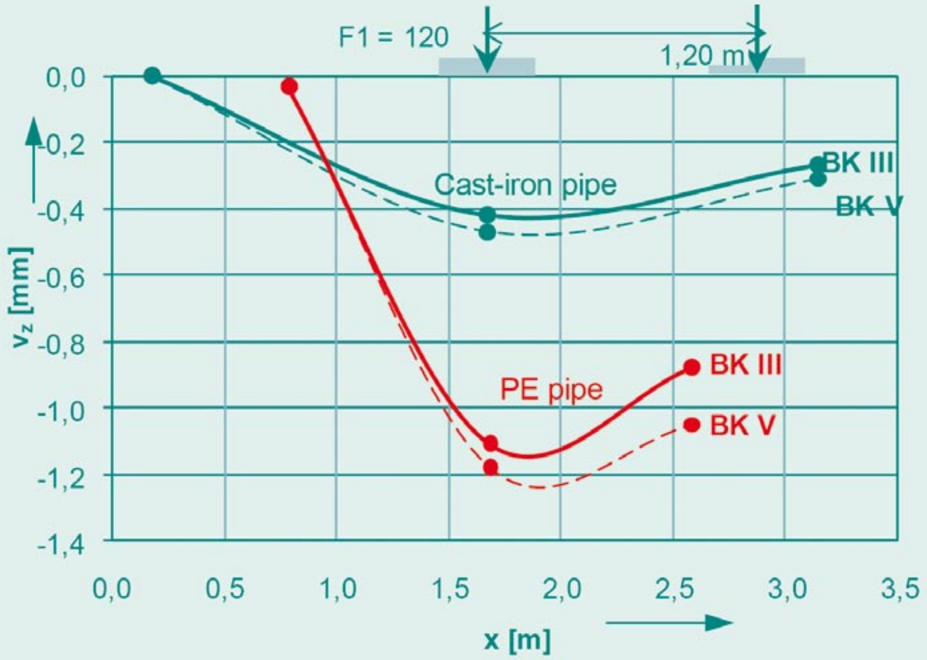


Figure 15: Plot of pipe deformations in the longitudinal direction for the normal load position (NL), for Construction Class III and V carriageways

crown, the side zones and the sole, and the pipe deformations, are evaluated.

Accordance is good in the case of the soil stresses, but the pipe deformations and stresses are generally lower than indicated by the calculation methods used up to now (ATV code A 127 [2], TR 1295, Part 3 [11] and the Finite Element Method).

Only the circumferential stresses are determined in ATV A 127 and TR 1295, Part 3, however, the stresses in the longitudinal direction of the pipe and the shear stresses, which are both also important in the case of shallow cover depths, are not taken into account; here, the tests provide approaches for the improvement of the computation models (e.g. the model of the elastically bedded beam).

A development against time (in this case: increase) of the pipe stresses is indicated for all pipe materials, i.e., the values measured do not decline toward zero after removal of the load on a test section and repositioning of the loading apparatus. The resultant ultimate stress can therefore be considered to be the result of a „loading history“.

The pipe materials investigated exhibit differing longitudinal load-bearing actions, the lowest being that of the profiled plastic pipes. Interruption of the longitudinal load-bearing action as a result, for instance, of a transverse crack in damaged pipes can be taken into account by means of higher mathematical crown loadings.

Tests performed using cyclical loads at 75% of maximum load (F_1 = 90 kN) and 106 load cycles result in a significant increase in soil stresses and a slight increase in soil compaction.

Close passage of a vehicle specified by the loading diagrams in DIN Technical Report 101, damaged carriageways and transition points in carriageway surface type result in increased loads which, in some cases, are covered by the dimensioning standards used up to now.

Other tests investigated the impact factor in the case, for example, of damaged carriageway surfaces, which was 1.2 to 1.5 in the preceding standard, and is included in the live traffic loads in accordance with [6]. Dynamic reactions of the pipe/soil system in case of sudden load application over the concrete pipe and the plastic pipe are also compared.

The results of this research project will, in future, permit more accurate dimensioning of shallowly covered pipelines below various roadway surfaces and during installation. They will be used in the revision of the body of rules for the calculation of buried waste-water conduits and pipes (ATV A 127).

It is thus now possible to better estimate the load exerted on damaged pipes with only shallow cover. The concept for concentrated area loads (vertical earth pressure and supporting lateral pressure) is, in addition, to be incorporated into the dimensioning of repair systems for Old Pipe Condition III.

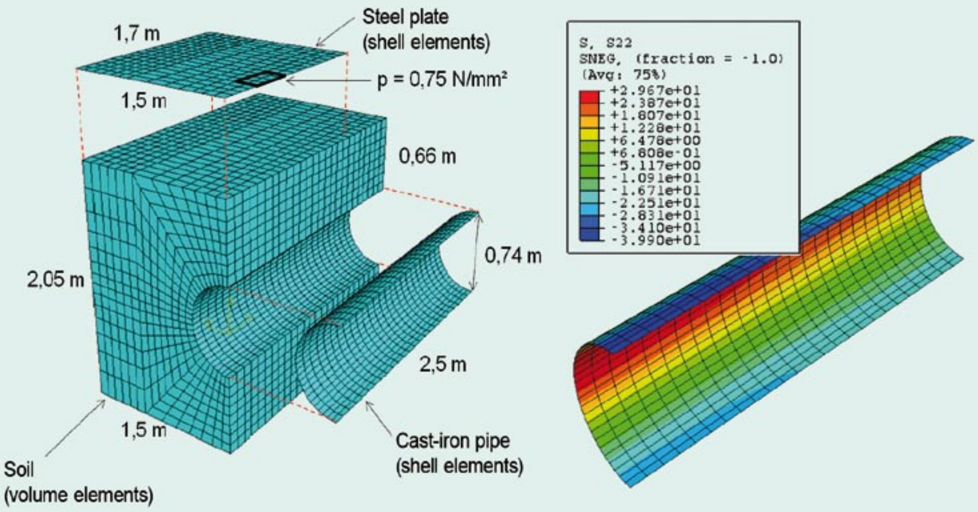


Figure 16: Three-dimensional FE model, circumferential stresses on the outer side of the ND 700 cast-iron pipe, h = 0.88 m, load position NL, Construction Class III asphalt carriageway

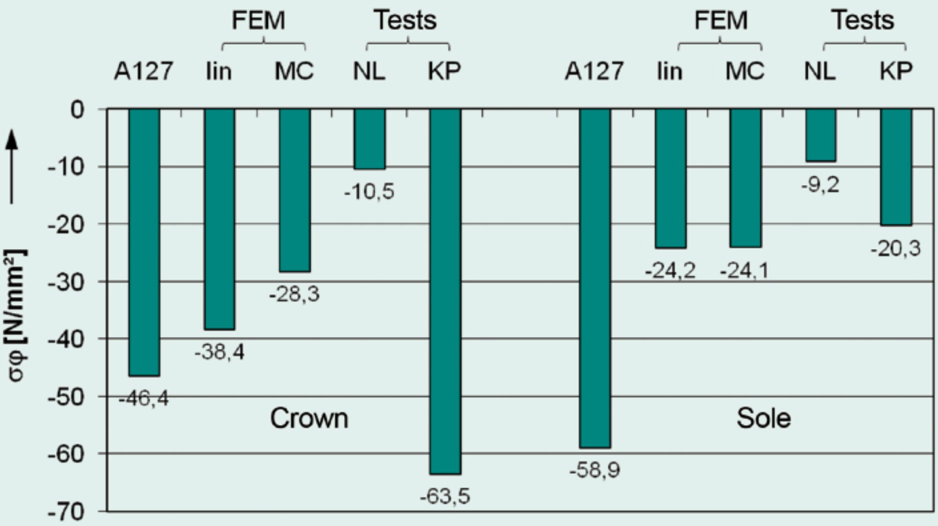


Figure 17: Circumferential stresses on the cast-iron pipe, sources: A 127 code, Finite Element Method (lin = linear soil law, MC = Mohr-Coulomb), tests: normal load position (NL) in accordance with Figure 2 at h = 0.88 m and Construction Class III, edge pressure (KP) at h = 0.40 m and Construction Class V

Authors
Prof. Dr.-Ing. Bernhard Falter,
Dipl.-Ing. Martin Wolters,
Univerity of Applied Sciences Münster

Dr.-Ing. Bert Bosseler,
Dipl.-Ing. Bianca Diburg,
Dipl.-Ing. Martin Liebscher,
IKT - Institute for Underground Infrastructure

References

[1] Falter, B.; Wolters, M.: Mindestüberdeckung und Belastungsansätze für flach überdeckte Abwasserkanäle (MIBAK). Research project IV-9-042 3E1, subsidized by MUNLV. Concluding Report dated December 19, 2008
[2] ATV-DVWK code A 127 (2000): Statische Berechnung von Abwasserkanälen und -leitungen, 3rd edition, Hennef.
[3] Steffens, K. (Ed.); Falter, B.; Grunwald, G.; Harder, H. (2002): Abwasserkanäle und -leitungen, Statik bei der Substanzerhaltung und Renovierung (ASSUR). Cooperative Research Project 01RA 9803/8, subsidized by BMBF. Concluding Report, Eigenverlag Inst. für Experimentelle Statik, Hochschule Bremen.
[4] Bundesministeriums für Verkehr, Bau und Stadtentwicklung (2001): Verkehrsprognose 2015 für die Bundesverkehrswegeplanung [BMVBS] (FE-Nr. 96.578/1999). Concluding Report, April, 2001.
[5] Hornung, K. (1984): Straßenverkehrsbelastung erdüberdeckter Rohre. Korrespondenz Abwasser 31 532-541.
[6] DIN Technical Report 101: Einwirkungen auf Brücken, 2nd edition, March, 2003, Beuth Verlag.
[7] ATV-DVWK code A 139: Einbau und Prüfung von Abwasserleitungen und -kanälen; June, 2001, Hennef.
[8] Radenberg, M.: Gutachterliche Stellungnahme zur Auswahl und Verlegung eines Pflasterbelages, Bochum 2007 (not yet published).
[9] RStO 01 (2001): Richtlinien für die Standardisierung des Oberbaues von Verkehrsflächen.
[10] TL Pflaster-StB 06 (2006 edition): Technische Lieferbedingungen für Bauprodukte zur Herstellung von Pflasterdecken, Plattenbelägen und Einfassungen
[11] TR 1295, Part 3 (2006): Structural design of buried pipelines under various conditions of loading – Part 3: Common method.

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IKT – Institute for Underground Infrastructure

Exterbruch 1
45886 Gelsenkirchen
Germany

phone: +49 209 178060
fax: +49 209 17806-88
email: info@ikt.de

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