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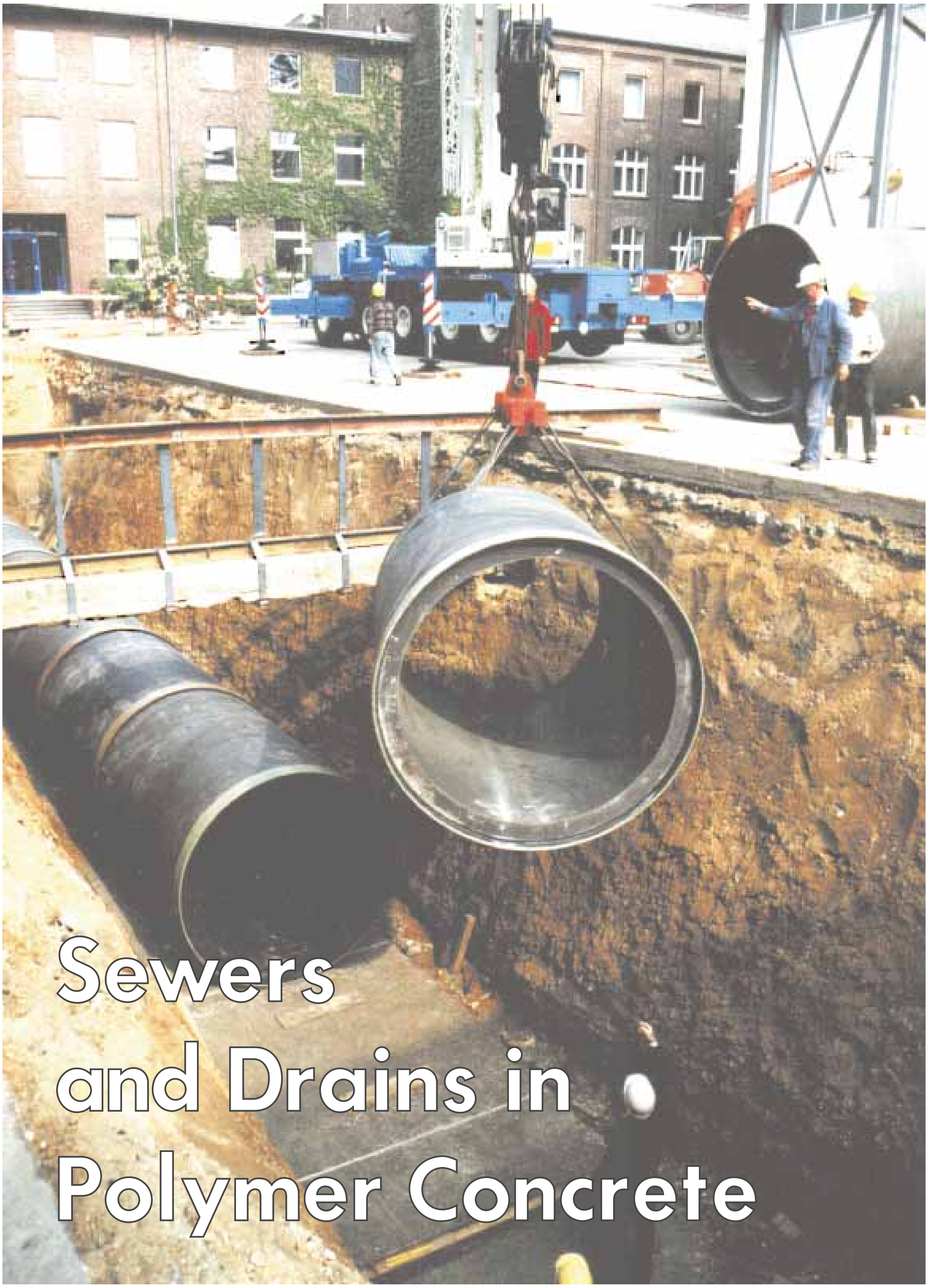

Sewers and Drains in Polymer Concrete

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The well proved mechanical and chemical performance of polymer concrete has been supplemented with improved manufacturing technology which now makes the material an ideal choice for pipes for use in microtunneling, jacking and sewer applications in general. This material is increasingly being used and world-wide licensing of this new teehnology will continue this trend.

Introduction

Highly filled thermosetting resin concrete has been used for decades in the chemical industry, in engineering construction (machine foundations), in the building industry (facade products, sanitary parts) and in electrical engineering due to its favourable properties, especially its strength and elasticity as well as its corrosion resistance. The material is also described as polymer concrete or mineral casting and is made up of the bonding agent, the thermosetting resin, and a large proportion of mostly mineral fillers. The development of pipes in polymer concrete dates from the early 1960s, The aim was to achieve substantial increase in resistance to chemical attack from the inside and outside and strength in respect of the stresses from external and internal loads whilst retaining the economical advantages of the pipe as a prefabricated finished part (1). Up until 1969 around 50 000 tonnes of pipe had been manufactured in Germany from polymer concrete in the nominal diameters DN 300 to DN 3500 using polyester resin or epoxy resin as the bonding agent in either prestressed reinforced or plain designs. These were mainly used and tested as waste water collectors in the chemical industry, so that even then statements could be made about the reliability of the product technology.

Despite these successes and the outstanding properties of the product, pipes in polymer concrete were not permanently accepted in the market at first. Manufacturing was abandoned after some time either for cost reasons or due to the fact that aspects of the manufacturing technology had not been adequately mastered. The processes for the production and manufacture of pipes and manholes in polymer concrete have been fundamentally improved over the past ten years, and it is now available as an economic alternative to other corrosion resistant pipe materials.

1 Polymer concrete sewer pipes DN 2000 in an industrial plant

2 **Laying of polymer coacrete sewer pipes DN 2000**

The Material

Pipes in polymer concrete consist of up to 90% quartzitic, oven dried fillers, i.e. mineral sands and grit with a grading curve of 0 to 16 mm with polyester resin as a bonding agent. They do not contain any cement, instead the polyester resin brings about the bond between the fillers after curing and gives the pipes the additional positive properties of elasticity. safety against fracture and corrosion resistance.

Plastics arc macromolecular compounds, i. e. large-scale molecules which have originated from the amalgamation of smaller basic molecules. “Polymer” (Greek) means “consisting of larger molecules”. Thus plastics are also described as high polymer materials and aggregates with plastic as a bonding agent are described as “polymer concrete”.

Polyester, vinylester or epoxy resins are used as thermosetting bonding agents, according to the requirements set for the chemical resistance of the material, These plastics are the so-called thermosetting plastics which are fully cured after a chemical reaction (polymerisation or polyaddition) and cannot be melted again. Quite the opposite to the thermoplastics, such as PVC and PE, which warp and finally melt under the effect of heat. This is caused by the different molecular structure, With thermosetting plastics spatial grid mole-

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cules arise during thc curing i.e. three dimensional chemical compounds, whereas with thermoplastics single chain molecules form with disordered structures, which can slide against one another. In addition thermosetting plastics do not become brittle at tempera- tures below 0° Celsius.

Manufacture

Polymer concrete pipes have been manufactured by various processes: by the centrifugal, centrifugal rolling and vibrating processes both with and without reinforcement, In the vibration process which is currently used the materials are mixed in a computer controlled metering and preparation installation and then loaded into vertical metallic moulds, consisting of an inner core and an external mould. After compaction on the vibrating table the pipe cures in the mould, is removed from the shell and then post cured in a tunnel kiln, Circular and oval pipes as well as special cross-sections such as manhole shaft pipes, cones and other auxiliary components can be manufactured in this way. The pipe joint is manufactured from glass fibre reinforced polyester resin as a separate connector coupling by the winding process. Thc elastomer, sealing and spacer rings arc laminated in with it. These meet the requirements laid down in DIN 4060 for “Sealing rings in elastomers for pipe joints”.

Properties

The following mechanical material properties are obtained on finished pipes in polymer concrete:

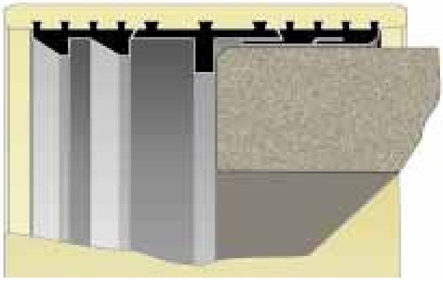
- Compression strength 100 - 120 N/mm²
- Modulus of elasticity 28 000 N/mm²
- Tensile strength 6 N/mm²
- Ring bending tensile strength 16 N/mm²
- Ring fatigue strength 6 N/mm²
- Abrasion resistance 0.2 mm per 100000 load cycles (Darmstadt procedure)
- Absolute wall roughness 0.1 mm

Polymer concrete pipes with polyester resin as the binder are resistant. against “very strongly corrosive and Aggresive” media in accordance with DIN 4030. According to the type of resin they can even be used in environments with pH values of 1 to 13. For highly polluted waste water polymer concrete pipes can also be manufactured with epoxy resin. The advantages of pipes in polymer concrete lie therefore in their high corrosion resistance against aggressive waste waters or soils, their great static load carrying capacity with their simultaneously relatively low weight, their low internal wall roughness and high abrasion resistance.

Sewer pipes

Sewer pipes in polymer concrete are manufactured with plain ends in 3000 mm construction lengths and in
diameters of DN 300 to DN 2500 as standard. There is no subdivision e.g. into normal wall and reinforced wall pipes. A uniform pipe wall per nominal width simplifies stockkeeping and covers 85% of all installation cases, using sand or gravel trench bedding materials. Recommendations on the bedding provide the planner with some initial assistance and these indicate which bedding installations give sufficient safety in the specific native soil conditions. The ATV work sheet A 127 Guideline for the Static Calculation of Drainage Channels and Pipes, 2nd edition 1988, formed the basis of the calculations and the recommendations were checked by a certified expert. If required, a detailed static calculation can be made for the precise conditions of the project. Manufacturing in dimensionally accurate steel costing moulds produces pipes with the lowest dimensional tolerances, which are circular over their whole length.
They are joined by means of a coupling made of glass fibre reinforced polyester resin with a permanently integrated elastomer double lip scal with centre stop web. The coupling is fitted on one end of the pipe in the works. The pipes and couplings are absolutely watertight when tested with a pressure of up to 2.4 bar. The elastomer seals are tightly anchored in the couplings and provide a chemical and ageing resistance which is equivalent to that of the pipes. Assembly is undertaken using standard commercial lubricants as is the case with all pushfit joints.

The pipes can also be supplied with 45° and 90° side connections.



3 GRP-Coupling

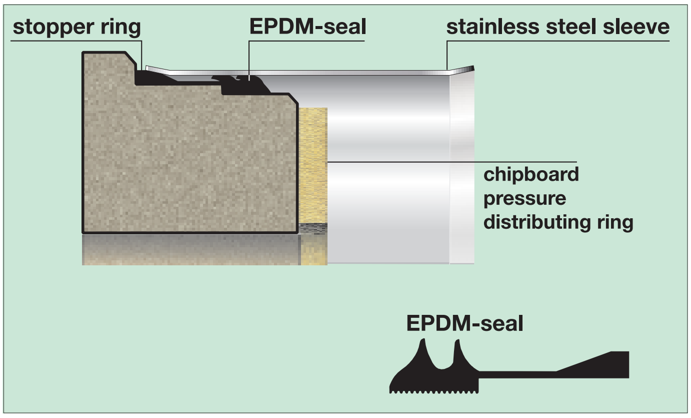
Non-Circular Sections

Oval or egg-shaped sections in polymer concrete are manufactured in dimensions in aiccordance with DIN 4263. Other dimensions, such as for example the egg-shaped sections of the “Sewer Construction Specification” of the City of Hamburg, which are split up into different “classes”, can also be supplied. The dimensions of egg-shaped sections are:

Width/height 300/400 to 700/1050 mm
Construction length = 2.5 m
Wall thickness 40 to 80 mm
Width/height 800/1200 to 1400/2100 mm
Construction length = 2 m
Wall thickness 90 to 150 mm

The joint is made in exactly the same way as for the circular pipes with a coupling of glass fibre reinforced polyester resin with a firmly integrated elastomer double lip seal with a centre stop web. This coupling makes assembly just as simple as with the circular pipes. To make handling easier, transport anchors are built into the base of the egg-shaped sections. Egg-shaped sections offer a range of advantages. They are hydraulically superior to the circular cross sections when there are marked fluctuations in the discharge rate associated with high wet weather flows and low dry weather flows. When there is a dry weather discharge the narrower cross section in the base provides better drainage through the higher flowrate. The correspondingly higher sweeping forces result in considerably less deposits. When there is torrential rainfall the water rises up to the top section and uses the wide reserve capacity. Furthcr advantages arise compared with circular pipes in respect of the carrying capacity through a lower load width and through the narrower trench width when pipelaying. Egg-shaped

4 Polymer concrete jacking pipe DN 1000 with steel sleeve



5 Joint of polymer concrete jacking pipes

Table 1: Range and dimensions of the most commonly used polymer concrete jacking pipes

internal diameter mm	external diameter mm	wall thickness mm	length m	permitted compressive force tons	permitted compressive force kN	pipe weight kg/m
150	200	29	1	16	160	37,5
200	275	37,5	1	21	210	62
250	360	55	1 and 2	53	530	117
300	400	50	1 and 2	51	510	122
400	550	75	l and 2	150	1500	249
500	660	80	2	190	1900	324
600	760	80	2	224	2240	380
700	860	80	2	240	2400	435
800	960	80	2	272	2720	490
900	1000	100	2	448	4480	700
1000	1184	92	2 and 3	414	4140	697/703
1200	1482	141	3	570	5700	1327
1400	1720	160	3	740	7400	1750
1600	1940	170	3	890	8900	2100

sections are moreover simpler to inspect and easier to clean.

Jacking pipes

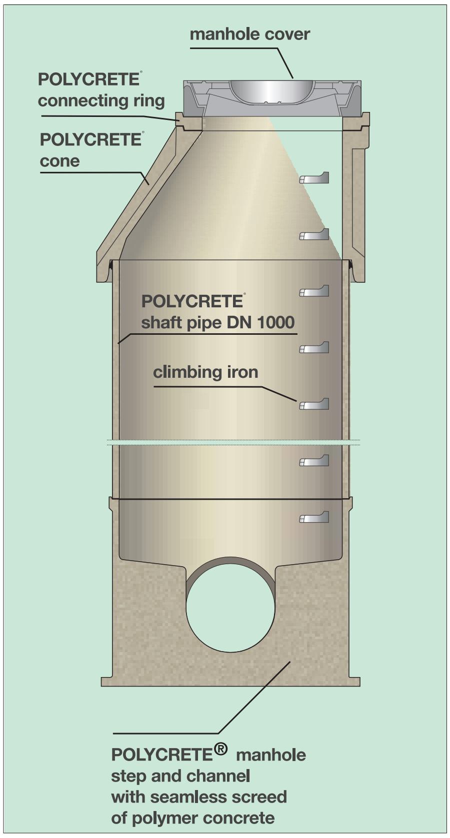
Jacking pipes in polymer concrete are manufactured with a wall thickness, which has been determined from experience to be adequate for the axial stresses of jacking. When calculating the permitted compression force, it is assumed that all the compressive forces have an eccentric effect upon half of the pipe crosssection through the steering movements of the tunnelling machine. The dimensions of the most commonly used diameters are listed in table l. In special cases larger wall thicknesses can also be manufactured to take higher compressive forces. The pipe joint consists of a mounted collar integrated into the pipe wall made of glass fibre reinforced plastic or alternatively of stainless steel. With a joint seal in microcellular expanded rubber and sealing sections on both sides, which are firmly joined to the pipe wall. A ring fitted in the works made of press board or knotless soft wood e.g. spruce or pine, in a thickness of 10 – 25 mm, according to the pipe diameter, ensures uniform pressure transfer between the ends of adjacent pipes.

The cross sections of jacking pipes do not have to be circular. Jacking pipes can be manufactured with egg-shaped, jawshaped or kiteshaped cross-sections. Thc pipes are locked together with holts, in order to prevent any
undesirable axial rolling of the individual pipes one against the other. The pipe joint is similar to that of the standard jacking pipes. The jacking is troublefree, but it must be ensured that rolling of the whole pipeline cannot occur during the jacking. The extremely high compression strength of polymcr concrete, the smooth surface of the pipes and the resulting low surface friction, as well as the flexible glass fibre reinforced plastic collar, which adjusts to the steering movements of the tunnelling machine and the movement of the following pipes, advantages the use of polymer concrete pipes in pipe jacking. The compressive forces increase only slightly, even after long stoppage periods (e.g. after a weekend) because of the smooth, nonabsorbent polymer concrete surface.

It is the “small extras” which often make pipe jacking considerably easier to carry out. For site arrangements, which make bentonite lubrication of the jacking pipes necessary, injection sockets are fitted in the pipe wall in the works with a check valve and blanking plug. For longer tunnelling lengths the necessary intermediate jacking stations can be supplied, adjusted precisely to the pipes and into which the hydraulic presses are inserted on site. Precisely fitting connection pieces are economically manufactured in polyner concrete for the different machines and asymmetrical pressure transfer rings can be manufactured for curved stretches,

Manholes

The basic idea when manufacturing manholes in polymer concrete was to construct a completely corrosion resistant and leak proof system together with the polymer concrete pipes for the drainage of waste water. In doing this as much work as possible should he transterred from the installation site to the workshop: manholes should be easily transportable and capable of being laid in one piece and should be supplied to the contractor at



6 Polymer concrete system manhole DN 1000

short notice with dimensions matching precisely those required at the site. This aim has been largely achieved by special manufacturing rnethods. Today even complicated manholes with many varied pipe connections, floor configurations, channel bends and internal and external bottom drops can he delivered to the site ready for installation, within a few days. The system manholes in polymer concrete correspond fully to the pipes in their material and wall design. The bottom section of the manhole consists of one piece. All types of pipes with the appropriate fittings for the respective type of pipe can be connected to it. The bottom section of the manhole is simply drilled and the appropriate fitting fixed tightly in place. This results in the following diameter correlations in accordance with DIN 4034:

System manhole		Connections
DN 1000	up	to DN 500
DN 1200	up	to DN 800
DN 1500	up	to DN 1000

Where there are larger connection diameters, manholes are manufactured from polymer concrete as prefabricated slabs, which are largely assembled in the works and then only have to be fixed together on site according to the transportation conditions prevailing. The step and channel of the system manhole are manufactured to the precise size from seamless polymer concrete screed on preformed sub concrete. The smooth contoured surface is particularly beneficial to the hydraulic flow. Climbing aids such as climbing irons, stirrups or ladders are fastened in the manhole wall with stainless lock nuts. The manhole is delivered in one piece with all the connections and with the shaft pipe stuck on (length 3 m maximum). It is lowered into the trench attached on a transport clamp and connected to the laid pipeline like a fitting. Where there are greater assembly depths further shaft pipes are butt jointed on site. 1n deep installations where DN 1200 and DN 1500 manholes are being used, cost reductions can be obtained by reducing the shaft diameter to DN 1000. This diameter reduction is norrnally made in the shaft at. heights above normal head clearance. The manhole is securely anchored against buoyancy uplift in the ground by the projecting manhole base. Where there is a very high water table the base projection can be enlarged on manholes with a continuous shaft. Manholes with a reduced shaft are always safe against uplift.

Fitting Lengths, Side Conneetions

Pipes and adapting pipes are manufactured to sixe in the works, so that no further machining is normally necessary on site. If an alteration in the route occurs at short notice or the precise manhole spacing are not fixed in time, then the manufacture of fitting lengths is possible on site. The pipes can be shortened using an abrasive blade. Since the pipes have the same outside diameter over the whole length, the adapting pipe produced in this way after cutting and chamfering can be joined to the pipeline without any problem. Side connections for property and road drainage with diameters DN 150 or DN 200 are manufactured in the works or on site with sockets or connections for approved pipe systems. The required bore holes for sockets or diagonal bores for 45° connection branches are performed with standard commercial core drilling instruments with a diamond drill head. 45° side connections are only required up to DN 400 as per ATV work sheet A 139. It is therefore advisable for all other connections to be at 90°.

Range of Applications

Pipes and inspection chambers in polymer concrete are generally used to build sewers and drains, which are operated as nonpressure pipelines. They can however also be operatcd as sewage pressure pipes with a nominal pressure of PN 1.6 in accordance with the minimum requirements for sewers in zone II water protection areas, where they are open laid (see ATV draft M 142).

Maintenance and Cleaning

It is not always possible to select the cross sections and falls of the channels. Discharge conditions will fluctuate and flow rates may not be high enough to remove deposits, thus cleaning work may be required. Nowadays virtually only high pressure cleaning is used for this work. It is increasingly necessary for operators to consider to what extent the individual pipe materials are stressed by the high pressure cleaning.

New test results (2) show a clear correlation between abrasion resistance and the capacity for resistance to stress from high pressure channel cleaning for various materials. It was moreover determined that a higher sand or filler content on the inner surface of the pipe wall considerably increases thc resistancc to high pressure cleaning. In the case of pipes in polymer concrete a high abrasion resistance and a very good resistance to high pressure washing is guaranteed by the uniformly high content of quartzitic fillers over the whole pipe wall. i.e. also on the inner wall of the pipes.

Standards

The basic standard DIN 54 815 ”Pipes and fittings in polymer concrete” has been prepared in working group 505.1 of the Plastics Engineering Standards Committee in DIN.

7 Benching of a polymer concrete system manhole DN 1000

The following standards must be complied with when manufacturing pipes in polymer concrete: Reaction resin with the moulded material propertics as per DIN 16946, part 2, at least type 1130. Quartz aggregates as per DIN 4226, part 1, table 3 (maximum grain 16 mm).

The following standards are applicable with regard to the laminate design of the connector coupling: glass according to DIN 61850-55, unsaturated polyester resin as per DN 16946, part 2, at least type 1130.

The elastomer sealing sections must comply with the requirements of DIN 4060.

Approval and Quality Assurance

The seal of approval PAI3939 was granted for sewage pipes in polymer concrete and its couplings in glass fibre reinforced plastics, by the Institut für Bautechnik (Institute for Structural Engineering), Berlin.

Pipes and components in accordance with this ruling may be used as nonpressure sewers laid underground and as pressurised sewer lines with a nominal pressure of PN 1.6 bar to drain sewage according to DIN 1986.

The pipes are subject to regular quality inspections which are subject to outside assessment by the Government Material Testing Authority (MPA) of North RhineWestphalia.

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