

Argumentation with the choice of clay pipes as sewer material.

Proposition: Clay unites all properties required for sewer pipes in an ideal manner

Argumentation from:

- 1. practical experience:**
long experience, camera investigations of old sewage pipes, successful use even in extremely critical circumstances;
- 2. scientific comparative research:**
from the physical and chemical structure of the material a number of beneficial properties of clay can be established;
- 3. comparison of standards:**
the number and level of the requirements and of the tests described in standards says a great deal about the properties required by the user;
- 4. physical characteristics of clay:**
uniform wall construction, smoothness and hardness of the wall, chemical resistance of clay and seals, high strength series, sealing at high values of angular deflection and radial load, temperature resistance;
- 5. product innovation:**
e.g. evolution to higher crushing strengths values, narrower tolerances, new product applications (larger diameters, jacking, relining...);
- 6. quality level:**
intensive product control, different (further) national product certificates, ISO 9002 quality labels;
- 7. wide possibilities for use:**
extensive product range of accessories and fittings (connections to other materials, crossings);
- 8. ecology:**
favourable ecological balance (concerning raw materials, energy, CO₂, NO_x, waste at end of life), long life expectancy;
- 9. high quality/price value:**
long depreciation period, advantageous investment;
- 10. future-oriented:**
extra safety regarding future developments (higher aggressiveness by concentrated waste water, higher temperatures, higher requirements of sealing). Meets the latest specifications (e.g. possibility of testing air-tightness in conformance with new European standard for the laying of sewer pipes);
- 11. budget-friendly for the client:**
with the new price structure clay can already on purchasing be more competitive than current sewer materials;
- 12. confidence at the sewer contractor:**
no unusual tools or installation techniques;
- 13. fast installation:**
with integrated seals, low insertion forces, fast manner of shortening;
- 14. budget-friendly for the receiver of the sewer piping:**
low maintenance costs, resistant to high pressure cleaning, simple to repair.

1. Practical experience:

Clay is one of the oldest known materials used for sewer construction. For the client, the chooser of materials and the user this brings a number of advantages, but also disadvantages. The advantages are numerous - the material is tried and tested, and once professionally laid it will easily have a life of a hundred years.

Disadvantages? Whoever has not followed the development of clay pipes in recent decades associates clay, perhaps lightly, with a few negative aspects seen with some very old pipes. With the current state of technology, however, these points have been superseded. This primarily concerns the sealing systems and the material strength. Before, sewers had to particularly remove soiled water. Clay was very commonly used for this. To improve drainage and because of the ever-increasing hardening of surfaces, more and more rainwater was ending up in sewers. The diameters of these pipes continued to increase. This meant other sewer materials could also meet the new requirements (removal of thinned waste water). In the meantime awareness had grown that to meet the requirements of the EU directive concerning waste water purification, it was necessary to decentrally separate the rainwater to the extent possible by re-use, buffering and infiltration at the source. In the western countries we saw that the alternative; building large rain reservoirs on the edge of the systems, often cost more money and was often insufficient in meeting the emission standards. Hence the major parallel interest in western countries for decentral measures to limit the flow in the sewers and to obtain closed off piping systems. This all led us back to the larger discharge transporters in the system and automatically to renewed interest in the material clay.

The long life expectancy of clay is undisputed. For the sealing materials the standard prescribes tests for extrapolations for sealing behaviour at 100 years. These are tests that can be compared with the tests for the synthetic pipes (relaxation, creeping). As distinct to what is established with some synthetic materials the curves - for the sealing materials of the clay pipe types with socket – show an asymptotic course and not sudden failing behaviour after, e.g. 50 years. Fig. 1 and 2 shows this progression for the rubbers and polyurethanes used by an important clay-pipe producer; Keramo-Steinzeug.

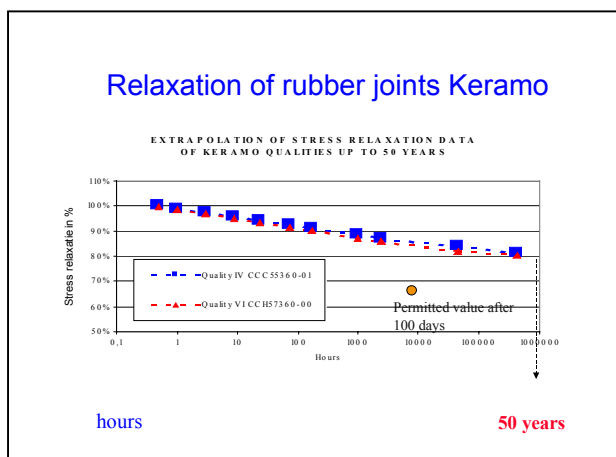


Fig 1

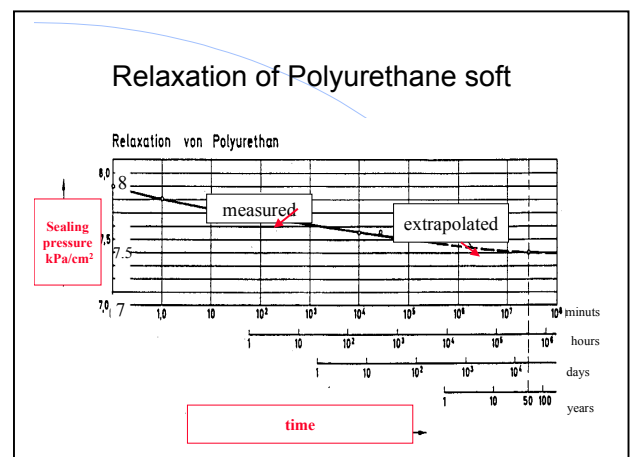


fig 2

These seals have now already been in use for 25 years. So, the wide-ranging series of tests provided for in the clay standards could be easily repeated on seals of removed pipes. The following paragraph is a description concerning the polyurethane seals.

During construction work in 1993 a clay pipe DN 400 - 25 years old – was removed. The piece of piping formed a part of a sewer system in a partly closed system in which camera investigations regularly took place, with no sealing faults being found. The pipe lay in the groundwater with 4 metres of water pressure. The concrete foundations provided at the time were chemically affected. The clay piping was intact both internally and externally. The concrete foundations were removed and the clay connection was subjected to a water pressure test in a laboratory with a 5-m water column and a radial load of 25 N/mm diameter.

Recovery of a 25 years old vc pipe



Material samples were taken from the polyurethane seal, tested and compared with current requirements. All the requirements were met. The properties are summarised in table 1.

Table 1: after 25 years the seal has all the properties required.

POLYURETHANE HARD

- Shore hardness
- Resistance to creeping
- Shape stability
- Behaviour at low temperatures
- Resistance to ageing
- Chemical resistance

POLYURETHANE SOFT

- Tensile strength
- Shore hardness
- Shape stability
- Behaviour at low temperatures
- Resistance to ageing
- Chemical resistance

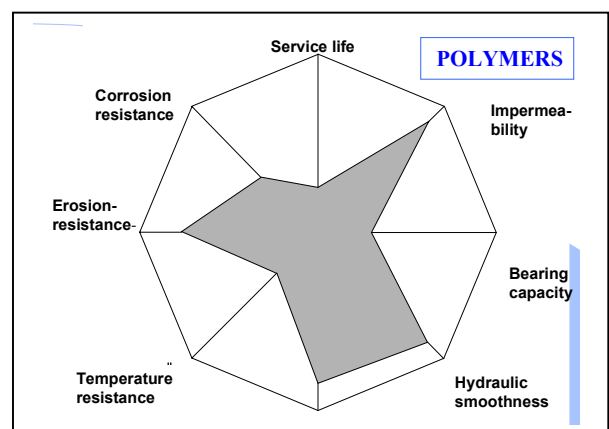
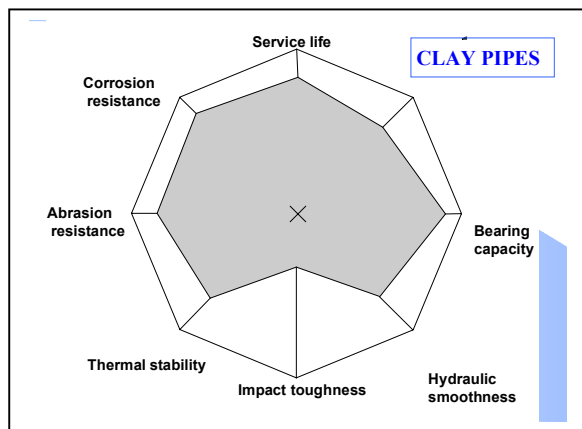
The deformation was measured on soft polyurethane. This amounted to 13.5%. The resulting calculated sealing pressure amounted to 1.0 N/mm² and was therefore four times the minimum value of 0.25 N/mm².

According to the conditions applicable at the time the pipe had to resist a crushing load of 45 kN/m. With the test, the pipe only broke at 82 kN/m.

Camera investigations in old clay pipes show that they often look like new. Because clay has proved its worth with extremely aggressive waste waters in areas including industry, extensions are often again used particularly now that stricter soil certificates are required and because of the desire to avoid any polluting of the subsoil.

2. Scientific comparative research:

Based on the chemical and physical properties which can be derived from the make-up of the material, the article¹ by G. Petzow analysed the functional characteristics of sewer materials. For this he goes back to the chemical compounds between atoms and the molecular, microscopic and macrostructural make-up. Eight intrinsic material values were analysed, and from this analysis values were obtained for 7 characteristics important to the user. These values are represented in an octagonal radar graph. The perfect octagon represents the most ideal sewer material. Professor Petzow comes to the conclusion that this ideal material does not exist, but that clay comes closest. The closer the properties come to the optimal values, the longer the life expectancy. This characteristic was therefore also included in the radar graph. The analysis was conducted for concrete, clay, pipes made on the basis of metals and polymers. (pvc , HDPE). Figures 3 and 4 below give two examples from this publication.



¹ G. Petzow, H. Schubert ; Materialeigenschaften in Spiegel des Kanalrohreinsetzes, Korrespondenz Abwasser N° 5/92

Comparison of standards:

In Western Europe Clay pipes are produced according to the European standard EN 295. Producers, users and control bodies were involved in the discussions which led to this standard. This standard came into being at a high technical level. The main characteristics from the previous clay standards DIN 1230 and the British standard are included, and even made stricter for certain points. In the standard many technical characteristics to be provided for sewer systems are described and supported by standard tests. This not only applies for the clay material, but also for the seals. This is the most comprehensive and demanding test programme for pipes that exists (European or national). In the general European standard concerning sewer pipes (EN 476) these characteristics and demands are only found partly and in a diluted form. The table below gives a comparison between a number of pipe materials for two important characteristics:

Characteristic	General	Clay	Cast iron	Concrete		
	EN 476 ¹	EN 295 ²	EN 598 ³	NBNB21-501 ⁴	PrEN XXX ⁵	DIN 4032
Watertightness test	To be tested to 50 kPa, for permitted water addition and test duration: see product standard. Moisture on the outside may not result from internal pressure.	To be tested with 50kPa internal and external pressure (higher test pressures can be specified). Max. permitted water addition for 15': 0.07 l/m ² . No moist patches may be visible on the outside. Tests to be carried out also with deflection and shear load	Test to 0.5 bar internal pressure and 1 bar external pressure, with no visible lack of sealing occurring. No limit value for permissible absorption.	To be tested with 200 kPa and checked for visible leaks. A value for permissible water addition is not given.	To be tested with 50kPa to DN 300 and 100 kPa for DN > 300. Moist patches on the outside are permitted.	To be tested with 50kPa for all diameters. An average of 3 measurements are taken. Result of the singular test may exceed the criteria by 30%. Permitted water addition for 15' is dependent on the pipe section and diameter (for round section 0.08 to 0.05 l/m ²)

Table 2

² Seven-part standard for clay pipes

³ Cast-iron sewer pipes

⁴ Belgian standard for reinforced concrete pipes

⁵ Draft European standard for concrete pipes (reinforced and not reinforced)

Characteristic	General	Clay	Cast iron	Concrete		
	EN 476 ¹	EN 295 ⁶	EN 598 ⁷	NBNB21-501 ⁸	PrEN XXX ⁹	DIN 4032
Crushing values	Reference is made to the product standards	The standard pipes available on the market fall under the crushing values 95, 120, 160, 200 and 240 kN/m	The crushing values are related to maximum permitted deformation to avoid cracks in the inner lining. These crushing values are significantly lower for most diameters than those for the currently used clay strength classes	The highest crushing series provided in this standard is the 135 series. To diameter 600 the clay industry offers higher crushing values.	Classes 90 and 135 are proposed	

⁶ Seven-part standard for clay pipes

⁷ Cast-iron sewer pipes

⁸ Belgian standard for reinforced concrete pipes

⁹ Draft European standard for concrete pipes (reinforced and not reinforced)

2. Physical characteristics of clay:

The table below gives a description, numerical value and the resulting advantage in practice for the user for a number of physical characteristics of clay material.

Table 3

Characteristic	symbol	value	meaning
Wall construction		Extremely fine-grain construction, high content of glass and quartz. Uniform monolithic wall construction, no sandwich structure	Uniform properties through the whole wall thickness, (clay and glazing), no problems with recycling
Longitudinal pressure strength	β_{LD}	100 N/mm ²	Up to three times of that for e.g. concrete. Clay jacking pipes therefore have thinner walls.
Ring bend tensile strength	β_{RBZ}	15-40 N/mm ²	Has a direct relationship with the crushing value. Because of refined raw materials choices and production techniques the strength of clay has increased greatly.
Strength of an adhesive connection	β_{KL}	30-35 N/mm ²	A very high value, far above the minimum requirement. This allows the composition of special clay parts by adhesion.
Modulus of elasticity	E_R	40-50 kN/mm ²	Clay has a rigid pipe body, but great flexibility in the connections. The E-modulus does not reduce in time. The material does not age and keeps its shape stability even under heavy loads.
Volume weight		22 kN/m ³	Clay pipes are usually lighter than e.g. concrete because of the narrower wall thickness. Otherwise the weight hinders floating.
Mohs hardness (from 1 to 10)		7	Clay is very hard (comparable with quartz). So, great resistance to erosion and high pressure cleaning.
Heat expansion coefficient	α	5.10 ⁻⁶	Because of this low value no special measures are needed such as compensators to accommodate expansion.
Heat conduction	λ	1.2 W/mK	Clay quickly radiates heat, so is very suitable at higher temperatures.

The following table gives the requirements for sealing made in the general standard for sewer pipes, and specifically those in the clay standard EN 295. Further, the references to the WN

295 standard are to even higher requirements than included in EN 295. The WN 295 lists are requirements in the context of a manufacturing standard which are also externally checked by Keramo-STG.

Table 4

Watertightness	prEN476		EN 295		other
from inside	0.4 bar		0.5 bar		2.4 bar (ATV A142)
from outside	0.4 bar		0.5 bar		
+ Angular deflection	< 300	30 mm/m	< 200	80 mm/m	100 mm/m (WN 295)
	300-600	20 mm/m	250-500	30 mm/m	50 mm/m (WN 295)
	600-100	10 mm/m	600-800	20 mm/m	30 mm/m (WN 295)
	> 1000	10 x 1000/DN	> 800	10 mm/m	
+ Radial load	10 N/mm		25 N/mm		25 N/m for Normal wall 50 N/mm for reinforced wall (WN 295)
Soil uniformity tolerances	< 300	6 mm/m	< 300	5 mm/m	> 400 - 4 mm/m
	> 300	2 % of DN	< 600	6 mm/m	> 400 - 1% van DN
			> 600	1 % van DN	(WN 295)
Chemical resistance	No specific provisions		fitted connection pH 2-12 H ₂ SO ₄ , HNO ₃ , NaOH, NaOcl		pH 1-13 (WN 295)
Interchangeability	No specific provisions		Within the same connection systems and crushing class		
Temperature change resistance	No specific provisions		80 hours: Cycles of -10°C and + 70°C		
Temperature resistance, long duration	DN < 200	45°C	7 days at 45°C		
	> 200	35°C			
Radial load test for short- and long term creeping	No specific provisions		< 6 mm for 3 months. When > 6 mm support socket during the test		

3. Product innovation:

Clay has evolved to offer greater strengths. This can be illustrated on the basis of the crush values in the standards and in production. Graph 5 shows this for diameter DN 400 normal wall. Compared with the situation before 1986, this pipe has practically doubled in crush value. This is due to intensive research work and also better types of clay, better production control, the ISO quality system, and investments in better control of the kilns

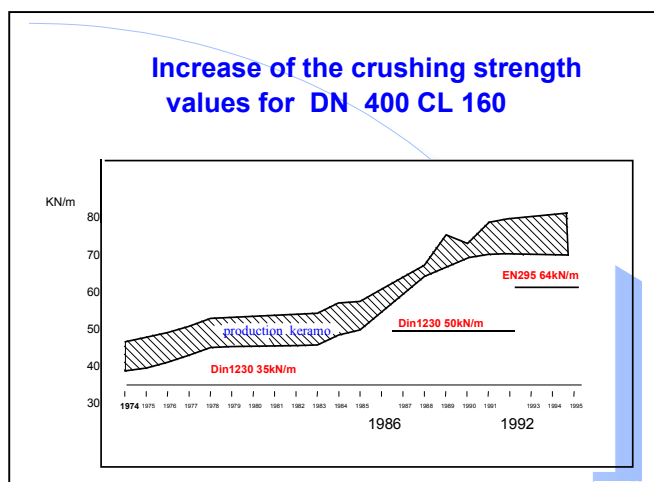


Fig. 5

Furthermore, much work has been done in recent years on more user-friendly laying. The insertion forces have been drastically reduced for diameters 200 to 400 so that they can be easily slid into each other with a hand lever. For DN 200 to 300 these insertion forces only amount to 80 to 200 kg, and for DN 300 to 400. This is approximately half the previous values. As a result, simple assembly is guaranteed, yet all requirements regarding sealing are satisfied.



According to the new European standard for the laying of pipes, the air pressure test at the construction site is also allowed as the test for the sealing of pipes. Much research has also been done in this area. These tests have been conducted successfully on clay pipes many times.

4. Quality level

6.1. Product certification

The clay products from Keramo-STG are periodically tested by various control bodies in accordance with European standard EN 295.

Table 5

Quality mark RAL-STEINZEUG	Güteschutz Köln Frechen
BSI	British Standards Institute, London
INISMA	Institut national interuniversitaire des silicates sols et matériaux, Mons
CSTB	Centre scientifique et technique du bâtiment, Marne-la-vallée
MA39	Magistrat der Stadt Wien, Versuchs- und Forschungsanstalt Wien

Table 1: approval bodies for Keramo-STG clay products.

After meeting the requirements made for clay pipes, accessories and clay chambers, Inisma gave permission to use the Benor quality mark.

6.2. Quality certification

To yet further raise and reinforce the quality level Keramo has been working for a number of years on the development of a quality system. As early as 1989 this already gave Keramo the quality certificates ISO 9002 and EN 92002, and this after intense examination by the British Standards Institute (BSI). At this time Keramo was ISO 9002 certified by two bodies, namely the BQA (Belgian Quality Organisation) and the BSI (British Standards Institute)

7. Wide possibilities for use:

Clay pipes are used for gravity sewer pipes. Pipes and fittings covered by the EN 295 standard will accept periodic hydraulic surcharge. In this area of use one can use clay very widely because of the extensive range of fittings (branches, bends, reducing sections) and accessories (special connections to connect to other materials).

8. Ecology

With the production of clay environmentally-friendly natural raw materials are used, these being various types of clay, chamotte (recycled vitrified clay material) and water. These raw materials are in abundance. They are indeed present in large quantities in many countries, even if high requirements are made of the properties of the types of clay required. After reclamation the clay pits are reworked into the landscape or used as landfills whereby the sealing clay layer functions as efficient protection against groundwater pollution.

As distinct from many other different pipe materials where the preparation of raw materials often takes place at separate production establishments, the clay procedure from clay to end product is accommodated in one coherent production process. This gives savings in energy for transport and energy recovery. With other pipe materials it is exactly the preparation of the raw material that is often an energy-intensive process - with clay the greatest energy input is with the baking of the material.

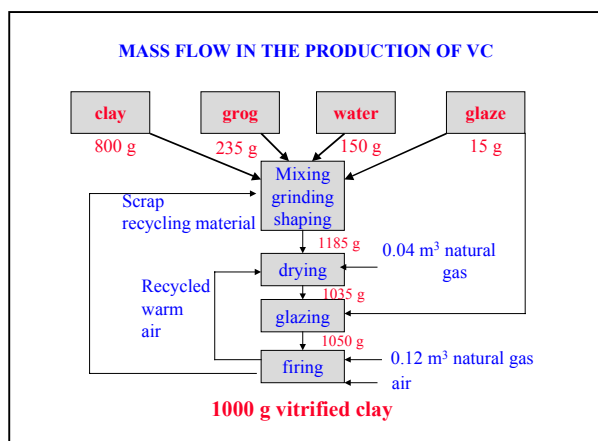


Fig. 6

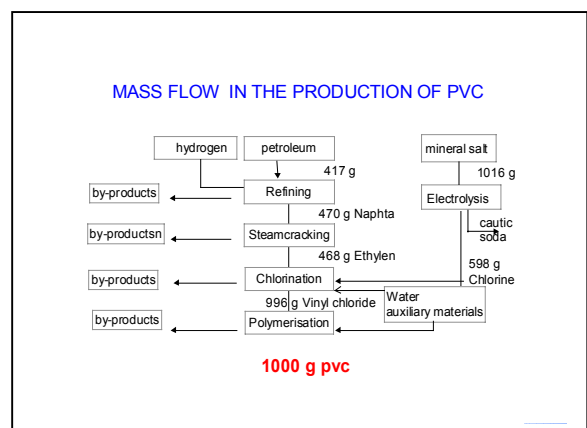


Fig. 7

Various studies are available which describe the ecological balance for various sewer pipe materials where the product history is examined from the cradle to the grave, and this not only for energy level but also for all environmentally relevant substances (SO₂, NO_x...)

By way of example, table 6 gives the values for the energy level of PVC and clay from the study by Prof. Jeschar et al published in Korrespondenz Abwasser¹⁰. From this it appears that for the production of one kilogram of PVC, ten times more energy is needed than for the production of 1 kg clay.

Energy consumption clay / pvc in MJ/kg pipe	
CLAY	PVC
● SUPPLY	● SUPPLY
- Clay 0.20	- petroleum 1.55
- natural gas 0.45	- mineral salt 3.05
● PRODUCTION	● PRODUCTION
- Processing 0.10	- petroleum 20.06
- drying 1.33	- refining 0.8
- firing 3.33	- steam-cracking 7.0
- electricity 1.20	- electrolysis 10.67
	- chlorination 16.0
	- polymerisation 5.67
	- extrusion 3.5
SUM 6.61	SUM 68.3

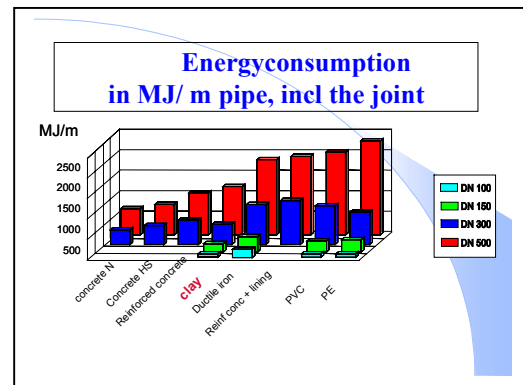


Table 6

Fig. 8

For a correct comparison the energy level per metre of sewer piping, the seal must obviously also be considered. For current sewer piping materials this can be seen in fig. 8, from which it appears that where corrosion-resistant materials are required, clay scores the best for the energy balance. This is even more distinct when one makes this comparison for a real project with fittings also involved and if one takes account of the life expectancy of the various materials.

From this comparison clay emerges as one of the most environmentally-friendly materials.

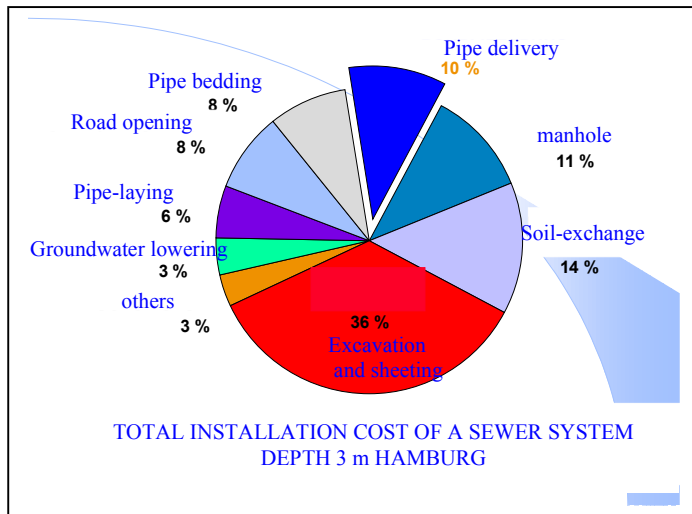
9. High quality/price value

From analyses of specifications and actual costs made for the installation of sewers it appears that the piping material itself only forms a small part of the total cost of the work. Depending on whether the installation is in a sensitive (e.g. shopping street with expensive street finishing) or less sensitive zone (e.g. open fields) the share of the sewer material will vary between 5 and 15%.

A modest extra cost for the clay material is then easily justified in view of the long life expectancy. Even in towns and cities where much attention and resources are devoted to the sewers, history teaches us that it is rare for the renewal of a sewer to take place within two generations unless the situation poses a real danger. Hence the more realistic option of having a sewer that is good for 80 to 100 years. In this perspective it can also easily be demonstrated that clay is the best choice. With the calculation methods on the basis of the LAWA guidelines, where in a consistent manner depreciation, interest, reinvestments and capital

¹⁰ Jeschar, R; Specht, E; Steinbrück, A:

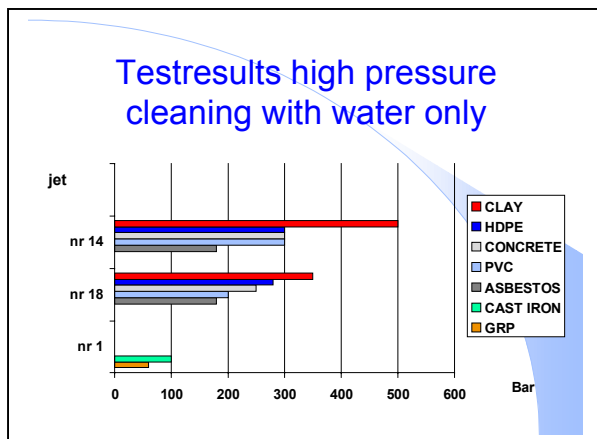
“Energieverbrauch und CO₂ Emissionen bei der Herstellung und Entsorgung von Abwasserrohren aus verschiedenen Werkstoffen”, Korrespondenz Abwasser 42 (1995) Heft 4, S. 537.



actualisation are taken into account, it appears that when one includes the values concerning the long life expectancy of clay one does obtain a high price/quality value.

10. Future-oriented

Clay not only excellently meets the traditional requirements made of sewer piping, it is also anticipating new trends and requirements which will be receiving more attention in the near future. As an example, the resistance to high pressure cleaning is being included as a test parameter in the clay standard. From a comparative study by the technical department of the city of Zurich clay appeared to score very highly. The tests were initially conducted with different nozzles with clean water in various sewer pipes without fittings. The pressure was increased until damage to the wall occurred.



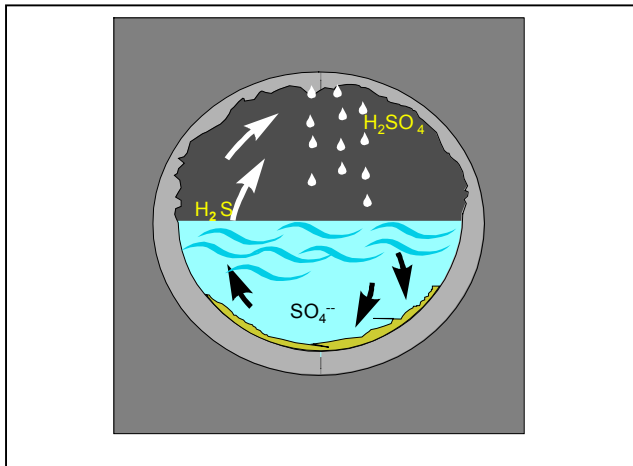
Pipe material	test pressure (120 bar)	damage
CLAY	+	NONE
PVC	O	Chamfered and roughened
FIBER-CEMENT	O	Erosion/removal
CAST IRON	O	Mortar layer grinded and chipped

For clay this was only the case from a pressure measured at the nozzle of 350 and 500 bar respectively. Private companies having to unblock sewers could draw their own conclusions from this.

In a second series of tests the piping materials coming into consideration for dirty water sewers were tested in a more complicated manner. The test was repeated 30 times with in

straight piping a deposit of a mixture of sand and fine material, the composition of which was dictated by the city of Hamburg. From this test the only material to emerge satisfactorily was clay.

Other important future-oriented characteristics for which clay proves ideal are; chemical resistance with high water temperatures, with high concentrations due to low water use, and the disconnecting of hardened surfaces. Biogenic sulphuric acid formation will be more common in the future because of the connecting of constituent networks, the optimising of storage in the system, and the integration of pressure lines. This means during its transportation the waste water will be more anaerobic and the ideal conditions will originate for biogenic sulphuric acid formation. Clay material is resistant to this form of aggressiveness.

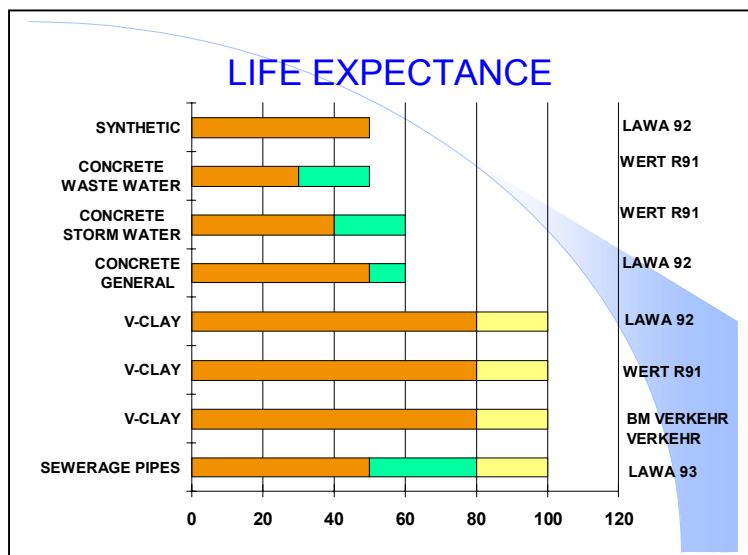


11. Budget-friendly for the client

With the laying of a separate system there are already economic advantages with the use of clay. Because of its smooth wall and erosion-resistance clay keeps its positive hydraulic benefits. Clay does not age. Subjected to loads, which may possibly change in the course of time due to excavations, clay always retains its sectional dimensions. This means, e.g. at the start of a district the waste water piping can easily start with a diameter of 200 when with light soiling there is a sufficient flow present to keep the wall sheering stress above a

minimum value. According to the investigation by Macke¹¹ the wall shearing stress for deposit free movement must be at least 1.0 N/m^2 . With an adverse small filling level of e.g. $h_T/d \geq 0.10$ (or 2 cm for DN 200) this means for a clay pipe with a roughness factor of 0.5 the minimum gradient must be 8 ‰. With a diameter of 250 this is 6 ‰. These are gradients that can easily be obtained at the start of the system. Rather than from generalising guidelines, minimum diameters must be determined on the basis of hydraulic parameters. Because one can assume that the trend towards separating and disconnecting will be intensively continued, the danger exists that within the foreseeable future too large piping will be located in the upward branches of the system. Smaller, less expensive pipes with a slightly steeper gradient, so with greater self-cleaning capabilities, can be laid and leave more space in road surfaces already being filled with cables and other lines.

If one takes account of long depreciation periods, an investment in clay is usually the least expensive solution. Depreciation periods of 80 to 100 years as recommend by the LAWA guideline tip the balance in favour of clay. Depreciation of 1 % per year then becomes possible.



¹¹ Macke, E.; Über den Feststofftransport bei niedrigen Konzentrationen in teilgefüllten Rohrleitungen, Dissertation, TU Braunschweig, 1982

Clay unites all properties important to sewers in an unparalleled manner. The contractor sometimes sees the impact-resistance compared with concrete as a negative aspect. However, this is often seen differently by the client - if the contractor is not particularly careful with the material and damage results, this will be clear with the handing over of the work and repairs can be made. Damage when laying other piping materials often only appears after the guarantee period.

12. Confidence at the sewer contractor

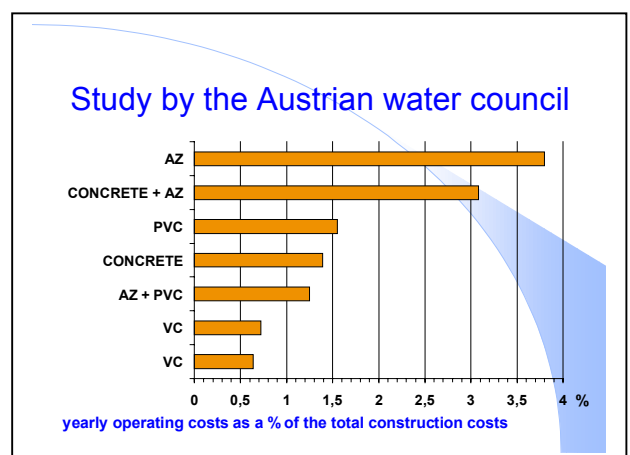
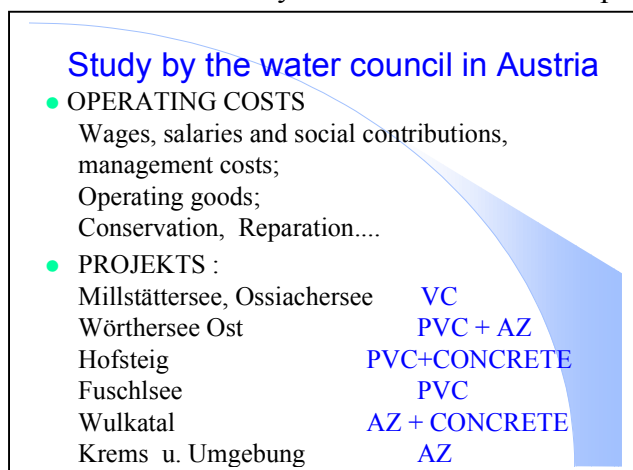
A qualified contractor disposes of the necessary materials and equipment to be able to easily lay clay. The cutting of clay pipes is much quicker than sawing through synthetic pipes.

13. Fast installation

Contractors are regularly kept up to date by technical training of conditions for laying and measures for working with the material more easily. Accordingly, great efforts were devoted to obtaining stable and reliable connections by drilling, insertion forces were reduced, and crush values were increased. Clay has already had integrated seals for 25 years which are extremely dimensionally stable. This guarantees fast installation.

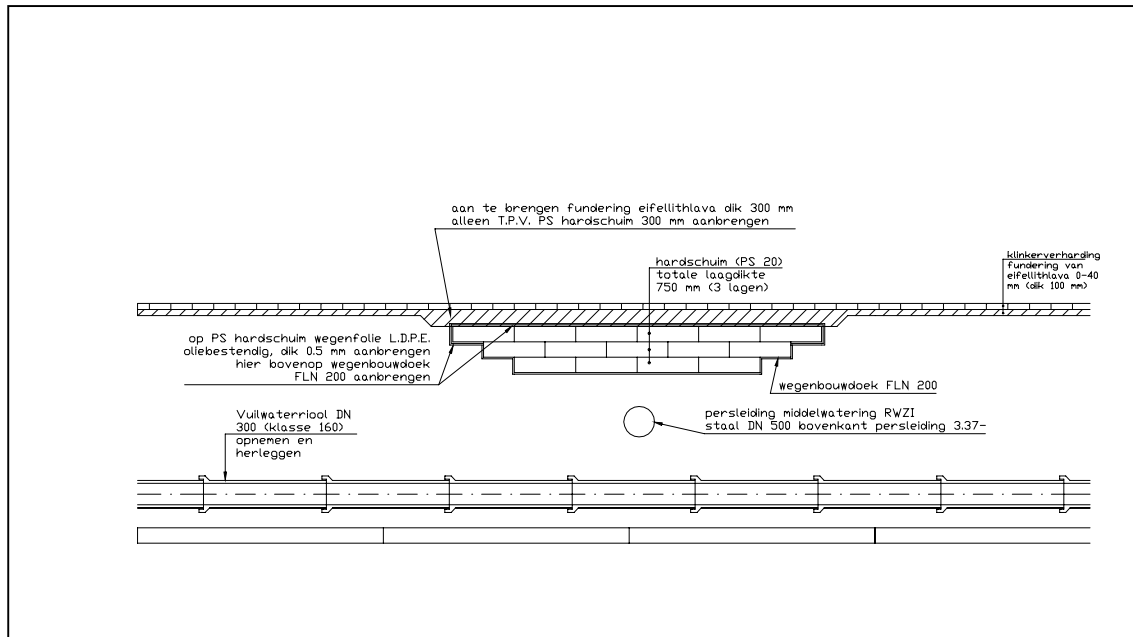
14. Budget-friendly for the receiver of the sewer piping

From research at Abwasserzweckverbände in Austria, who among other things is responsible for the maintenance and upkeep of their sewer systems, it appeared that the costs for maintenance with clay is the lowest when compared with other materials.



Clay excellently stands up to maintenance by high pressure cleaning (see above). If repairs do have to be carried out, a wide range of accessories are available. Subsequent connecting to clay sewers causes no problems because the round section remains permanently.

Clay pipes in subsoils liable to settling have also already been dug up and removed in various projects in the Netherlands. It then appeared that re-use of the pipes including seals was possible.



From these 14 arguments it does appear that in very many circumstances clay is the material of the future for a good-functioning sewage transport system. Clay unites all the characteristics needed for a sewer system in an ideal manner. This also gives clay a longer life. And this suits the client and the financier, after all, not every generation can build its own sewer system, and this does not have to be necessary with clay being so durable.

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3/06/98