LEADING-EDGE

International Water Association

Leading-Edge Asset Management

2nd IWA Leading-Edge Conference & Exhibition on

Strategic Asset Management

Strategic selection of materials for wastewater networks

Per Kristiansen[1] Leif Sigurd Hafskjold[2], Terje Skaug[1] and Sveinung Sægrov[2]

[1] Oslo municipality, Water and wastewater, [2] SINTEF Water and environment

LESAM 2007 – Lisbon 17-19 October 2007

Oslo's aims for wastewater network management

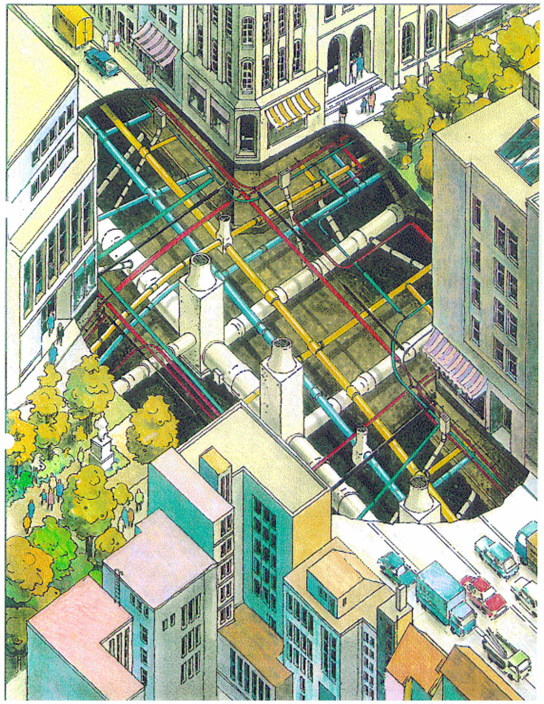
- Minimize social impacts caused by network failures
  - Flooding of buildings (stress, compensation)
  - Excess CSO effluent to local streams
  - Traffic disruption
- Minimize environmental impacts caused by failures
  - Emission and energy use of products used for new pipelines
- Minimize costs
  - Optimise Life Cycle Cost
  - Minimize compensation

Minimizing social impact

- Improving existing system to minimize floods in buildings and pollution for streams and fjord
  - Identify bottlenecks (hydraulic and structural)
  - Predict collapses and blockages
  - Upgrading vulnerable parties of network

Minimizing costs

- Long lasting materials
- Avoid spots where operation and maintenance are necessary (sags, structural overload)
- Postpone rehabilitation of existing pipelines
- Documentation, records at reception and for existing pipes (transparent system)



Minimizing environmental impact by material selection (for use in Oslo)

+ favourable, - unfavourable, 0 neutral

Criteria/ Pipe material	**Ceramic**	**Concrete**	**Plastic**
Production	+	+	0
Transport (depending on construction site)	-	+	0
Laying (depending on soil conditions)	0	0	+

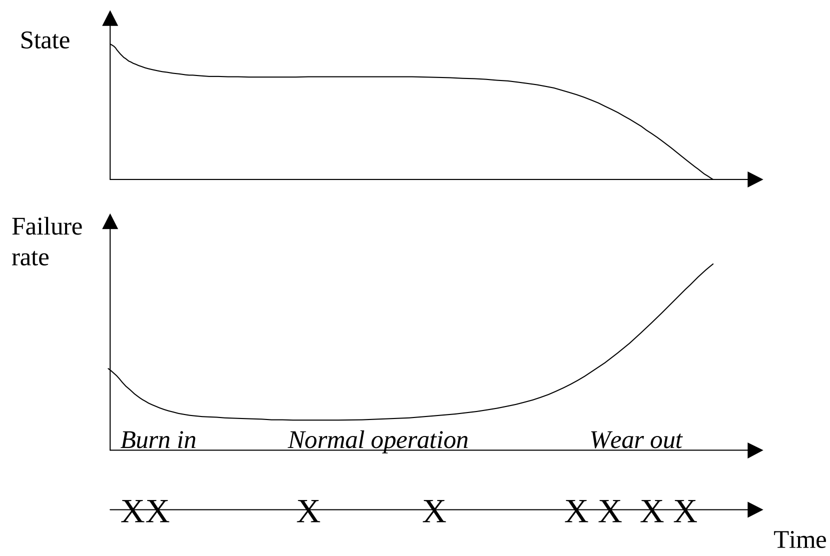
Environmental impact of pipe materials, all stages in life cycle

Material	Energy	CO_2	NO_x	SO_2, SO_x
Ceramic	+			
Concrete	+	0	0	+
PE	-	0	0	-
PP	0	+	0	-
PVC	0	+	0	-

Life Cycle Assessment

Minimizing cost and optimising performance at each step of service life

- Production
- Transport
- Construction
- Operation and maintenance
- Renovation
- Replacement
- Reuse of materials



Life Cycle Assessment
Failures at different stages of service life

Failure type	Correction by construction	Operation and maintenance	Renovation	Replacement (service life ended)
<u>Wrong design</u>				
Hydraulic capacity			x	x
Localization				x
<u>Failure by construction</u>				
Missing strength	x		x	x
Sags		x		x
Leakage			x	
Roots		x		
Inserted pipe	x			
<u>Operational problems</u>				
Blocking		x		
Biological growth		x		
<u>Old pipes</u>				
Crack		x	x	
Deformation				x
Collapse				x

Degradation of pipes

- Degradation mechanisms, general
  - Chemical degradation
  - Corrosion
  - Crack growth
- Comprehensive pipe material improvement has taken place, normal expected service life all main materials as of to-day > 100 years
- Care needs to be taken for
  - Concrete in agressive soil or transporting H_2S containing sewage
  - Plastic pipes when external load is extra high

Degradation mechanisms

Material	**Degradation mechanism**	**Critical material property**	**Comment**
Concrete not reinforced	Chemical degradation	Porosity	Porosity is connected to production practise
Concrete reinforced	Corrosion reinforcement	Porosity Concrete cover over reinforcement	Old pipes sometimes produced with too small concrete cover
Ceramic	Crack growth	Fracture toughness	
Glass fiber reinforced polyester GRP	Crack growth		Damage may occur internal when load is exposed external
PP non-pressurised	Deformation	E-module, wall thickness	
PVC non-pressurised	Deformation	E-module, wall thickness	
PVC pressure pipes	Crack growth	Fracture toughness	First generation pipe has lower fracture toughness compared to later productions
PE pipes for renovation	Crack growth	Surface fractures	
PE pipes for pumping	Crack growth	Surface fractures	Not known as a problem(after 1974)
CIPP (Polyestersleeve)	Not known		

General pipe material properties as of to-day

Material	Advantages	Disadvantages
Concrete pipes	Normally good corrosion protection Wide application Strong	Surface damaged if rough handled Heavy Corrosion under septic condition Corrodes if low pH
Ceramic pipes	Resistant to chemical attacks, no corrosion Strong	Brittle – careful handling required Short pipe length, many joints Heavy
Plastic pipes	Light Resistant to chemical attacks (normally) Resistant to wear and tear Hydraulic low-friction surface Flexible	Exposed to certain types for chemical attacks Require good quality installation work
Corrugate pipes	Light Large product specter from simple and low-price to advanced and costly	Require good installation work Buoyancy effect may occur due to water pressure or frost
Constructed pipes	Light Resistant to corrosion	Brittle Require good installation work
Ductile iron pipes	Strong Stable when corrosion protected	Need corrosion protection Heavy

Properties of historical pipes
To be considered for rehabilitation planning

Material	Period	Properties
Ceramic pipes	1860-1920	Brittle, cracks occur
	1960-	Stronger pipes, limited experiences (Norway)
Concrete	1900-1945	Local production, high porosity and prone to deterioration, but often competent pipeline work
	1945-1970	Local production, variable quality, large external load due to pipe construction methods, prone to damage. First generation rubber gaskets, many connection failures
	1970	Increased strength (300%), improved production leads to more even quality and lower porosity. Better pipe construction quality due to control and regulations. Much less exposed to failures compared to older concrete pipes.
PVC	1965-1980	First generation pipes, missing knowledge on pipe construction, many deformations, some joint failures
	1980-	Better material quality, gaskets of synthetic rubber
PE	1965-	Joint welding quality variable, improved routines have reduced problem

Recommendations to Oslo 1/2

1. No reason to make difference between Ceramic, Concrete, PE, PP, PVC with regard to service life and performance. Certain risk aspects should be addressed:
   - Concrete in aggressive soil
   - Old reinforced, non-reinforeced concrete pipes,
   - Welding of plastic pipes, light-weight pipes
2. Adequate control level for pipe construction works
   - Avoid construction failures that will increase need for operation and maintenance (sags, overloading, leakages)
   - Documentation of construction works according to defined standards. Active control to be performed.
3. VAV should establish routines to avoid use of pipes which are not first-class
   - Requirements on documentation of pipes and pipe equipment (certificates on raw materials, manufacturer, production series, strength, standard applied)
4. Important to safeguard that documentation from pipelines constructed is recorded
   - Collect and improve documentation, one single record database, transferrable, easily accessible for sewer company staff

Recommendations to Oslo 2/2

5. Minimize energy consumption and CO_2, NO_x and SO_2 discharge
   - A thorough study on energy consumption and discharges from production and transport is necessary
   - If transport is a major factor for environmental impact, this will favourise local manufacturers
6. Avoid unecessary rehabilitation of pipes
   - Accurate pipe records required
   - Probability of collapses and blockages to be calculated from structural and hydraulic information
   - Identify potential impact of pipe failures and cost of preventive actions
   - Take action where this is necessary (only)
7. Safeguard wastewater network flow and self-cleansing capacity and avoid clogging due to grease
   - Analysis of flow and self-cleansing capacity of vulnerable parts of network

LEADING-EDGE

International Water Association

Leading-Edge
Asset Management

Thank you for listening!