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Economic feasibility study on the usage of water-draining formwork liners "ZEMDRAIN®" of the Du Pont company based on the "Guidelines for the Performance of Cost-comparison Analysis" by the Länderarbeitsgemeinschaft Wasser (Federal States Special Working Group for Water Matters), 1993

1. Subject

An economic feasibility study on the usage of water-draining formwork liners "ZEMDRAIN®" of the Du Pont company shall be carried out in connection with the reconstruction of the activated sludge tank for the clarification plant of Bad Homburg. The base-data for the parameters "Costs" and "Lifetime" which are of relevance to the comparison of diverse variations are based on the specifications of the Du Pont company and were not verified by the expert assessor. Data required for supplementation are based on values derived from the routine experience of the expert assessor.

2. Description of project alternatives

Variation	**1**	Manufacture of component without "ZEMDRAIN®"; investments **I1**; first reinvestment **after 10 years;**
Variation	**1.1**	Refurbishment measure of the grade "SAN1"; next required reinvestment **RI1 after 10 years**;
Variation	**1.2**	Refurbishment measure of the grade "SAN2"; next required reinvestment **RI2 after 15 years;**
Variation	**2**	Manufacture of component with "ZEMDRAIN®"; investments **I2;** first reinvestment **after 20 years;**
Variation	**2.1**	Refurbishment measure of the grade „SAN1"; next required reinvestment **RI1 after 10 years**;
Variation	**2.2**	Refurbishment measure of the grade „SAN2"; next required reinvestment **RI2 after 15 years;**

In a **refurbishment measure of the grade "SAN1"** it is assumed that a service life of 10 years can be attained for the refurbished component by using a specific surface treatment method to be chosen in line with the code of practice of the ATV-working group 1.1.4 "Corrosion of waste-water channels" (yet-to-be published).

In a **refurbishment measure of the grade "SAN2"** a surface treatment to be chosen in line with the code of practice of the ATV-working group 1.1.4 "Corrosion of waste-water channels" (yet-to-be published) is carried out. In this process, the thickness of the layer to be treated is increased on one hand, while on the other hand, a larger process-technical effort is exerted for the achievement of a lower water-cement ratio. In this case, a service life of 15 years is assumed for the refurbished part. In relation to a practical implementation, it can be assumed that a mathematical service life of over 15 years for surfaces already once refurbished, can be attained only under further increased technical and financial expenditure which cannot be justified from a general economic point of view.

3. Determination of costs and mathematical service life

Level of costs and/or reference period:

1994

Mathematical service life of the entire concrete structure:

35 years (depreciation period)

Basis of cost data:

*1 Specifications of the Du Pont company, not verified by expert assessor;
*2 See article “Ahrens/Sackmann", P. 4, b (internal surfaces);
*3 Price index 1992 to 1994;

Investments:

I2 (variation 2) = I1 (variation 1) + 30.00 DM/m^2 concrete surface*1

Mathematical service life till initial complete refurbishment of surface (1. RI):

Variation 1 (without "ZEMDRAIN®"): 10 years*1
Variation 2 (with "ZEMDRAIN®"): 20 years*1

Reinvestments or refurbishment expenditure for smooth, rising tank walls:
(dependent on the chosen refurbishment quality, not on the initial variations)

Refurbishment of the grade “SAN1": RI1 = 230.00*2 x 1.06*3 = 244.00 DM/m^2 concrete surface
Refurbishment of the grade “SAN2": RI2 = RI1 + 80.00 = 324.00 DM/m^2 concrete surface

Mathematical service life until next complete surface refurbishment (2. RI):
(dependent on chosen refurbishment quality, not on initial variations)

Refurbishment of the grade “SAN1": 10 years
Refurbishment of the grade “SAN2": 15 years

Running costs for surface cleaning and protection:

New construction without “ZEMDRAIN®" or refurbishment in accordance with the standard “SAN1":
LK1 = 1.0 LK = x1 DM/(m^2 x year)
New construction with “ZEMDRAIN®" or refurbishment in accordance with the standard “SAN2":
LK1 = 0.8 LK = x2 DM/(m^2 x year)

Running costs for surface cleaning and protection are reduced as quality standard increases (better water-cement-ratio, smoother surface, less depositions, better cleaning options). The benefits derived from this option for variation 2 (usage of water-draining formwork liners) are not taken into consideration mathematically. They are only schematically illustrated in the project cost series.

4. Suitability for cost-comparison account

Both variations are capable of the same performance, the mathematical service life of the reference structure is identical, there are no variation-specific cost-effects towards third-parties. The "Guidelines for the Performance of Cost-comparison Analysis" by the Länderarbeitsgemeinschaft Wasser (Federal States Special Working Group for Water Matters), 1993 thereby constitute a suitable instrument for the comparison of the variations.

5. Financial-mathematical preparation

The periodical accrual of costs for a construction project covers the period from the first preliminary investigations on the execution of the construction over reinvestments that may become necessary up until the end of the service life and also contains current operational and maintenance costs. All project-specific cost accruals can be illustrated as in picture 1.1 and 1.2 as the respective *project cost series*. The period between the beginning of the investment phase and the end of the operational phase (planning horizon) is regarded as the *investigation period*. Since different values are attributed to accruing costs at different times, the payments of a cost series cannot be simply added up. On the contrary, they must be converted on the basis of their value (dynamic method) for the purpose of comparison at a common applicable period (reference period). The value of a nominal cost-factor in the *reference period* is referred to as the *cash value* of this payment in accordance with what is applicable to a cost-series which characterises a project – the *project costs cash value.*

Payments made before the reference period shall be *compounded (accumulated)*, while subsequent ones shall be *discounted.*

The required periodical weighting of the nominal costs is done with the aid of the *financial-mathematical conversion factors* in which two basic base items are assumed. On one hand, the weight in which the lesser or higher valuation for future or past cost-effects is reflected as against such that are applicable to the reference period. This is reflected in the *interest rate.* On the other hand, the period between the actual accrual of cost and the reference period is determinant to the scope of deviation from the nominal costs and the accompanying cash value, i.e. the amount that must be discounted or accumulated *(interest period).*

The coupling of *real interest rate, nominal interest rate and inflation rate* has been taken into consideration in the financial-mathematical conversion factors and the accompanying recommendations. Finally, attention is drawn to the fact that the reference period for the temporal weighting of payments is completely independent of the choice of the base year used for the *price level of the cost-calculation.* (For the purpose of clarity, explanations in extracts are quoted from "Guidelines for the Performance of Cost-comparison Analysis" by the Länderarbeitsgemeinschaft Wasser (Federal States Special Working Group for Water Matters), 1993).

The alternatives to be compared indicate the same service life at the same investment period, in such a way that the prerequisites for a simple cost-cash value and/or annual cost-comparison are given.

The cost-series (picture 1.1 and 1.2) clearly reveal the time of accrual of the variation-dependent cost-types (investments, reinvestments, running costs) as well as the amount accrued.

To be able to add-up these cost-factors in a correct value-related manner and thereby compare the cost series, the nominal costs (of every alternative) distributed over the investigation period, must be converted to the reference period. The cash values are then obtained.

In the case in question, the first step to the determination of the cash values of cost is contained in an update of specified cost data to the cost level of the basis year 1994 which is the bottom line of the calculation.

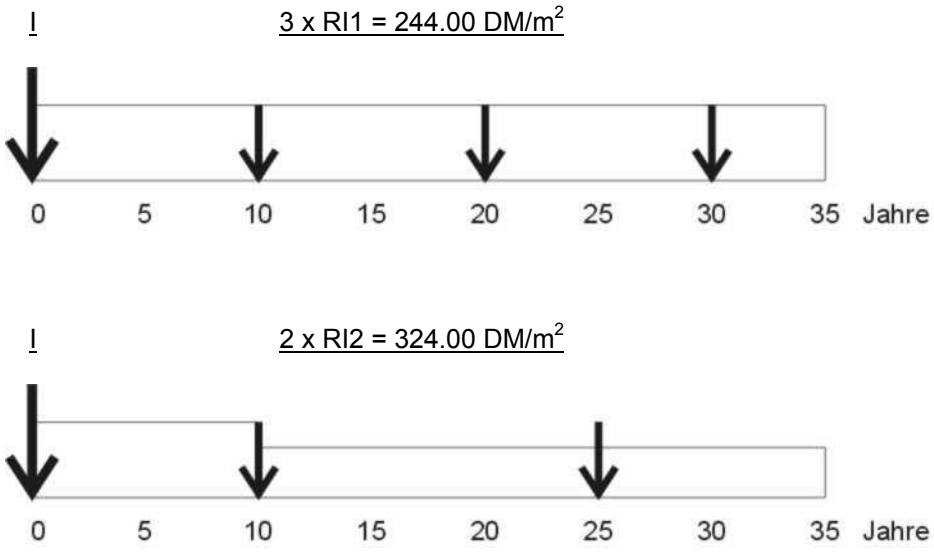
The investment cost difference of 30.00 DM/m^2 of concrete surface between the variations “Conventional formwork" and “Formwork system including water-draining formwork liners" corresponds with the cost-level of 1994 as well as the cost-difference for the various quality standard of surface refurbishment. The price specification of 230.00 DM/m² of inner wall area related to the refurbishment measures performed in 1992 was updated to the cost level of 1994 in section 3, using a mixed index of 1.03 (see LAWA-Guidelines, Chapter 3.3.2). The second step to the determination of the cash values of cost is contained in the discounting of costs accrued as reinvestments after the reference time. This is done in accordance with the equation:

$$RI\ (t=0) = RI\ (t=n) \cdot (1+r)^n \cdot 1/(1+i)^n = RI\ (t=n) \cdot \text{factor 1} \cdot \text{factor 2}$$

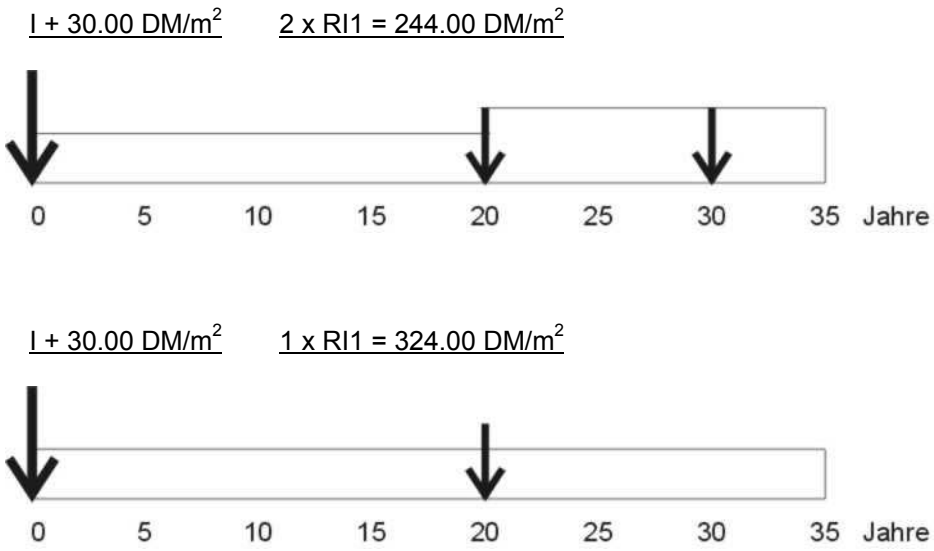
with n = resulting period between reference time and time of reinvestment
r = real rate of price rise
I = real interest rate

In the case in question, a real, i.e. an inflation-adjusted 1% rate of price rise is assumed (see LAWA-Guideline, chapter 3.3.3), the real, inflation-adjusted rate of interest is fixed at 3% (see LAWA-Guideline, chapter 4.3).

A determination of the cash values of cost for the variation to be considered can be seen on tables 1 and 2.



Picture 1.1: Project cost series of the variation 1 "conventional formwork method";
refurbishment measures of the construction quality “SAN1" or “SAN2" illustrated as reinvestments “RI1" or “RI2";
(running costs LK are schematically illustrated, but however not mathematically taken into consideration in the following calculation)



Picture 1.2: Project cost series of the variation 2 "water-draining formwork liner";
refurbishment measures of the construction quality “SAN1" or “SAN2" illustrated as reinvestments “RI1" or ”RI2";
(running costs LK are schematically illustrated, but however not mathematically taken into consideration in the following calculation)

Position	Sum	Investi-gation period	Time	Price index	Real interest	Factor 1	Factor 2	Cash value
	DM/m^2	a	a	%	%	-	-	DM/m^2
Investments:								
- I1	I	35	0	1.0	3.0	-	-	I1
Reinvestments:								
- RI1	244.00	35	10	1.0	3.0	1.10	0.744	200.00
- RI1	244.00	35	20	1.0	3.0	1.22	0.554	165.00
- RI1	244.00	35	30	1.0	3.0	1.35	0.412	136.00
Sum of cash value: (running costs LK1 & LK2 from picture 1.1 not taken into consideration)								501.00

Table 1.1: Determination of cash value for variation 1 (convent. formwork type), refurbishment measures of the construction quality “SAN1";

Position	Sum	Investi-gation period	Time	Price index	Real interest	Factor 1	Factor 2	Cash value
	DM/m^2	a	a	%	%	-	-	DM/m^2
Investments:								
- I1	I	35	0	1.0	3.0	-	-	I1
Reinvestments:								
- RI2	324.00	35	10	1.0	3.0	1.10	0.744	266.00
- RI2	324.00	35	25	1.0	3.0	1.28	0.478	198.00
Sum of cash value: (running costs LK1 & LK2 from picture 1.1 not taken into consideration)								464.00

Table 1.2: Determination of cash value for variation 1 (convent. formwork type), refurbishment measures of the construction quality “SAN2";

Position	Sum	Investi-gation period	Time	Price index	Real interest	Factor 1	Factor 2	Cash value
	DM/m^2	a	a	%	%	-	-	DM/m2
Investments:								
- I2	I1 + 30.00	35	0	1.0	3.0	-	-	I1 + 30.00
Reinvestments:								
- RI1	244.00	35	20	1.0	3.0	1.22	0.554	165.00
- RI1	244.00	35	30	1.0	3.0	1.35	0.412	136.00
Sum of cash value: (running costs LK1 & LK2 from picture 1.2 not taken into consideration)								331.00

Table 2.1: Determination of cash value for variation 2 (water-draining formwork liner), refurbishment measures of the construction quality “SAN1";

Position	Sum	Investi-gation period	Time	Price index	Real interest	Factor 1	Factor 2	Cash value
	DM/m^2	a	a	%	%	-	-	DM/m^2
Investments:								
- I2	I1 + 30.00	35	0	1.0	3.0	-	-	I1 + 30.00
Reinvestments:								
- RI2	244.00	35	20	1.0	3.0	1.22	0.554	219.00
Sum of cash value: (running costs LK1 & LK2 from picture 1.2 not taken into consideration)								249.00

Table 2.2: Determination of cash value for variation 2 (water-draining formwork liner), refurbishment measures of the construction quality “SAN2";

6. Comparison of costs

The alternatives to be compared indicate the same service life at the same period of investment in such a way that the prerequisites for a simple cash-value comparison of costs are given.

The illustration of the project costs series can be derived from pictures 1.1 and 1.2. It is obvious from the cost series that the accrued cost types (investments, reinvestments, running costs) may come up in different amounts and at different periods or intervals in a variation-dependent manner. To be able to add-up these cost-factors in a correct value-related manner and thereby compare the cost series, the nominal costs (of every alternative) distributed over the investigation period must be converted to the reference period. The cash values are then obtained.

The related cash values of cost were determined on the basis of a usage period of 35 years in line with the "Guidelines for the Performance of Cost-comparison Analysis" by the Länderarbeitsgemeinschaft Wasser (Federal States Special Working Group for Water Matters), 1993.

This was done for the variations shown on page 2 which are differentiated on the basis of the formwork technique (variation 1: conventional formwork, variation 2**:** water-draining formwork liners) and on the basis of the execution quality of the refurbishment measures (SAN1: lifetime of the refurbished component = 10 years, SAN2: lifetime of the refurbished component = 15 years). An explanation of the method is given on pages 3 and 4.

Based on the cash values of cost shown in table 3, the cost-reducing influence of an application of water-draining formwork liners is obvious in the case of new construction. Moreover, the scope of influence of the execution quality of the refurbishment measures on costs is also shown.

	Variation 1 Conventional formwork	Variation 2 Water-draining liners
RI1 Execution quality "SAN1"	501.00 DM/m^2	331.00 DM/m^2
RI2 Execution quality "SAN2"	464.00 DM/m^2	249.00 DM/m^2

Table 3: Compilation of the cash values of cost

A minimization of the cash values of cost (table 3) as well as a minimization of the reinvestment cycles (shut-down, construction status) required during the entire mathematical service life of the entire construction work can be undertaken by a reasonable stipulation of quality standards for new constructions and refurbishment work.

Solution 2 "Usage of water-draining formwork liners for new construction" + "Refurbishment measures of the construction quality SAN2" with a cost-cash value of 249.00 DM/m² therefore represents the economically and operationally recommendable variation.

Hanover, in November 1995

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