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Life Cycle Analysis of three Finnish Standard Bridges

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1 Introduction

This research focuses on life cycle costs and life cycle assessments of standard bridges. The life cycle analysis of standard bridges is a part of the Nordic ETSI project. The name of the project ETSI, consists of words "***E****linkaareltaan* ***T****arkoituksenmukainen* ***Si****lta*" and it could be translated "Lifelong Adapted Bridge" [1]. The bridge life cycle analysis consists of life cycle costs, life cycle assessment and bridge aesthetics. All analysed bridges belong to bridge site categorization class IV, which stands for ordinary bridges. Due to bridge site categorization class IV, bridge aesthetics is not included in this research.

The three analysed bridges were steel reinforced cantilever slab bridge, steel reinforced deck composite beam bridge and prestressed concrete beam element bridge. All the compared bridges have been chosen from standard bridge guidelines of Finnish Transport Agency. Compared bridges are typical waterway and road bridges, and the bridge deck lengths are approximately 20 meter and effective widths are 7.5 meter.

The life cycle thinking is coming increasingly important in civil and bridge engineering. The importance of life cycle assessment and overall life cycle costs are a part of "lifelong adapted bridge" thinking. Lifelong sustainable bridges are going to be adapted in bridge designing in order to obtain more cost-efficient bridges. This research was conducted as a part of Nordic ETSI project and was made by Tuomo Rantala from Finnish Transport Agency. The guidance of this research was conducted by Lic.Sc. Timo Tirkkonen and M.Sc. Minna Torkkeli from Finnish Transport Agency.

2 Etsi project [1]

ETSI project is a Nordic bridge lifetime optimisation management project, in which programs are developed to calculate bridge life cycle costs (LCC) and life cycle assessment (LCA) and to analyse bridge aesthetics. Programs developed for LCC and LCA calculations were utilized in this research.

WebLCC is a server based program to calculate bridge life cycle costs. Main parameters needed for calculations are:

- bridge investment cost
- coming maintenance and repair actions, which includes maintenance and repair periods and costs
- traffic disturbance caused by maintenance and repair, which includes maintenance and repair actions influence times, traffic disturbance costs and lengths, average daily traffic and reduction in speed limits
- Internal rate of interest.

BridgeLCA is Excel based program, which exploits also Matlab algorithm. BridgeLCA includes emissions used material and it is utilized to calculate bridge LCA and environmental impacts. In order to perform LCA calculations, are following parameters needed:

- amounts of material used in bridge construction,
- journeys to and from work, and material transportation distances and
- material consumption due to repair and maintenance actions.

3 Compared bridge type

This standard bridge life cycle analysis compares three types of Finnish standard bridges: steel reinforced cantilever slab bridge, composite beam bridge with steel reinforced concrete deck and prestressed concrete beam element bridge. Length of the superstructure is approximately 20 meter in every compared standard bridge. In cantilever bridge the bridge span is though 14 meter, which is smaller than in other two bridges.

Bridge cost estimates are calculated according Finnish Transport agency's cost estimate instructions and unit prices [2].

3.1 Steel reinforced concrete cantilever slab bridge

First analysed bridge is steel reinforced concrete cantilever slab bridge. The bridge is designed according Finnish Transport agency's "Teräsbetoninen ulokelaattasilta" standard-project drawings [3]. Single span bridge's span length is 14 meter and the length of cantilevers is 2.5 meter. Effective width of the bridge is 7.5 meter and overall width 8.3 meter. The length of the superstructure is 19 meter and the overall length of the bridge is 25 meter. End trusses and wing walls are chosen according standard-project drawings Bulc4.

Bridge waterproofing consists of double rubberized bitumen layer, under which is also epoxy waterproofing. Protective coating over the waterproofing is made from asphalt concrete AB6/50. The borders of the edge beams are also waterproofed by rubberized bitumen brushing. Between the asphalt layer and the edge beams is also installed joining compound of rubberized bitumen.

Transition slab's length is 5 meters and prepared cast-in situ. Bridge railings are standard type open railing H2 and in the middle of the bridge is also high safety net. Other bridge equipments are according standard-project drawings, such as surface water pipes, dribble pipes and charge pipes.

In the front of cone is stone rip-rap in the slope, and on the sideward of the cone and on embankment is turfing.

Bridge cost estimate is 147 000 € at earthwork cost indices of 135.9 %. Used cost indices are calculated at November 2009. Bridge cost estimate is presented at appendix 1.

3.2 Steel reinforced concrete deck composite bridge

Second analysed standard bridge is steel reinforced concrete deck composite bridge, which is designed according Finnish Transport Agency's "Teräsbetonikantinen

liittopalkkisilta II" standard-project drawings [4]. The span of the bridge is 19.45 meter and the length of the superstructure is 20 meter. Effective width of the bridge is 7.5 meter and overall width 8.3 meter. Overall length of the bridge is 27.6 meter.

Bridge superstructure consists of two steel girders and steel reinforced concrete deck, which are functioning together as composite structure. Cross beams are also used to stiffen the deck. Bridge deck is prepared cast-in-situ, and the end beams steel reinforced concrete.

Bridge waterproofing is similar, such as in cantilever slab bridge presented in chapter 3.1. Moreover, in bridge equipment belong laminated rubber bearing as well as elastic joint sealing expansion joint.

Bridge cost estimate is 159 000 € at cost indices of 135.9 %. Bridge cost estimate is presented at appendix 2.

3.3 Presressed concrete beam element bridge

The third compared standard bridge type is prestressed concrete beam elemenet bridge. The bridge is designed according Finnish Transport Agency's standard project drawings "Jännitetty elementtisilta" [5]. The span of the bridge is 19.4 meter and the total length of the superstructure is 20 meter. The effective width of the deck is 7.5 meter and the overall length is 8.3 meter.

Bridge girders consist of four prestressed concrete elements and bridge deck is cast-in situ. Slenderness ratio of bridge (L/H) is 20. Bridge equipments are similar as in chapter 3.2 presented composite bridge.

Bridge cost estimate is 154 000€ at cost indices of 135.9 % and it is presented at appendix 3.

4 Life Cycle costs

Analysed life cycle costs consist of bridge investment cost, maintenance and repair costs, traffic disturbance and bridge demolition cost in this report. The life cycle costs were calculated using 2 % interest rate and the chosen year of calculation is the bridge opening year. The chosen maintenance and repair actions were only the predictable actions, such as renovation of the edge beam and renewal of waterproofing.

Traffic disturbance costs are composed of the delay of the road users caused by maintenance and repair actions. The calculated traffic disturbance costs come from the decreased speed and actuating length, from where time delay is calculated for road users and multiplied by unit costs for different road users. Travel time savings for vehicle traffic is 16.09 €/h and for heavy traffic 56.02 €/h according to Finnish Road Administration guideline "Tieliikenteen ajokustannusten laskenta" [6]. Average daily traffic for all bridges is 6000 vehicle per day.

Bridge life cycle costs were calculated using WebLCC program presented in chapter 2.

4.1 Steel reinforced concrete cantilever slab bridge

Investment cost for steel reinforced concrete cantilever slab bridge consist of bridge cost estimate. The bridge cost estimate is in total 147 000 € and per bridge square meter 780 €/m^2. Price per square meter is calculated according Finnish Road Administration Bridge cost estimate using total length and effective width [2].

Maintenance actions under service life for the bridge are different cleaning actions as well as patching of the parapet and railing paintings. Bridge inspections are also calculated as bridge maintenance actions in life cycle calculations.

Repair actions under service life are composed of edge beam renovation, waterproofing renewal, repaving as well as renewal of railing and parapet. The predicted service lives for those parts are according their design ages:

- renovation of edge beam 25 years
- renewal of waterproofing 35 years
- repaving 10 years
- renewal of railing and parapet 50 years.

Bridge demolition cost is 10 % of investment cost. Overall life cycle costs are in total 239 000 € calculated to bridge opening year using 2 % interest rate. Life cycle cost per bridge square meter is thus 1270 €/m^2 and per deck square meter 1860 €/m^2. Bridge life cycle costs are divided as follows

- investment cost 147 000 €
- maintenance costs 23 000 €
- repair costs 60 000 €
- traffic disturbance 7 000 €
- demolition cost 2 000 €

Bridge life cycle distribution is presented in figure 1.

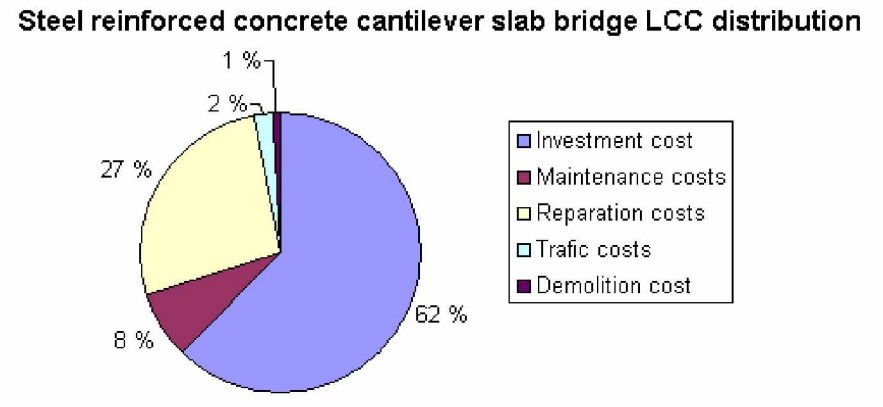

Figure 1. LCC distribution of steel reinforced concrete cantilever slab bridge.

4.2 Steel reinforced concrete deck composite bridge

Investment cost for steel reinforced concrete deck composite bridge 159 000 € according to cost estimate. Price per bridge square meter is 770 €/m².

Maintenance actions are likewise the same as for steel reinforced concrete cantilever slab bridge presented in chapter 4.1. Moreover, for composite bridge repair actions belong repainting of steel beams as well as maintenance and cleaning of expansion joints and bearings.

Repair actions under bridge service life are furthermore likewise as in steel reinforced concrete cantilever slab bridge. The similar repair actions are renovation of edge beam, renewal of waterproofing, repaving as well as renewal of railing and parapet. In addition, to composite bridge repair actions belong renewal of expansion joint and bearing every 35 years under major overhaul.

Bridge demolition cost is 10 % of investment cost. Overall life cycle cost for composite bridge are in total 305 000 € calculated to bridge opening year using 2 % interest rate. Cost per bridge square meter accrue thus 1470 €/m² and per deck square meter 2030 €/m². Bridge life cycle costs are divided as follows

- investment cost 158 000 €
- maintenance costs 62000 €
- repair costs 72 000 €
- traffic disturbance 10 000 €
- demolition cost 2 000 €

Bridge life cycle cost distribution is presented in figure 2.

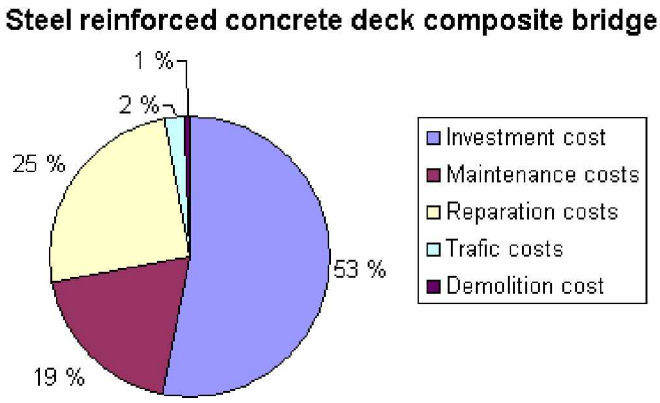

Figure 2. LCC distribution of steel reinforced concrete composite bridge.

4.3 Presressed concrete beam element bridge

The investment cost of the prestressed concrete beam element bridge is 145 000 € according to cost estimate. Price per bridge square meter is 690 €/m². Demolition cost of the bridge is 10 % of the investment cost. Maintenance and repair actions of the element bridge are likewise the same as for steel reinforced concrete deck composite bridge excluding the repainting of steel girders.

Overall life cycle costs of the prestressed concrete beam element bridge is in total 284 000 €. Price per bridge square meter accrue thus 1 270 €/m² and per deck square meter 1 890 €/m². Bridge life cycle costs are divided as follows

- investment cost 154 000 €
- maintenance costs 45000 €
- repair costs 75 000 €
- traffic disturbance 8 000 €
- demolition cost 2 000 €

Bridge life cycle cost distribution is presented in figure 3.

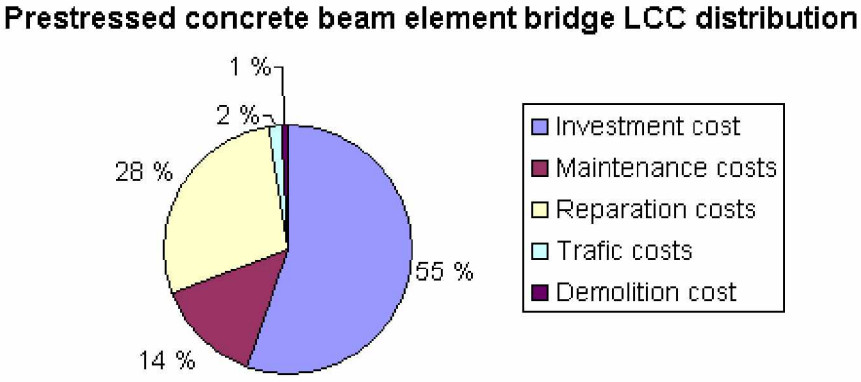

Figure 3. LCC distribution of prestressed concrete beam element bridge.

5 Bridge life cycle assessment

Life cycle assessment for standard bridges was performed by calculating material amounts used for bridge parts as well as for construction, maintenance and repair. Used material amounts are multiplied with emission loads in order to obtain environmental impacts. Transportation of workers and goods was ignored in life cycle assessment due to challenging evaluation. Moreover, the total transportation emissions would be closely-spaced thus making comparison of the materials more sensible.

Environmental impacts were determined using the BridgeLCA program presented in chapter 2. Amounts of environmental impacts were evaluated using measured emissions of Western Europe at 1995. [1]

Environmental impacts are categorised in six factors:

- Abiotic depletion, equivalent emission Antimony Sb,
- Acidification. equivalent emission sulphur dioxide So_2
- Eutrophication, equivalent emission phosphate PO_4
- Global warming potential, equivalent emission CO_2
- Ozone layer depletion., equivalent emission Trichlorofluoromethane CFC-11
- Photochemical ozone layer creation, equivalent emission ethylene C_2H_4.

Combined effect of the environmental impacts was calculated using weighting of emissions according to United States Environmental Protection Agency's factors. Weighting factors are presented in table 1.

Table 1. Weighting factors of environmental impacts according to US-EPA [1].

	ADP	AP	EP	GWP	ODP	POCP
Weighting factors	5	5	5	16	5	6

The weighted comparison between standard bridges is presented in table 2. In comparison, the environmental impact of the steel reinforced concrete deck composite bridge is largest and steel reinforced concrete cantilever bridge's is lowest. Figure 4 present the weighted accumulation of environmental impact of standard bridges.

Table 2. Environmental impact comparison.

Weighted environmental impact, comparison value for effects	Total impact [-]	Per deck square meter [-]
Steel reinforced concrete cantilever slab bridge	2257514	15842
Steel reinforced concrete deck composite bridge	2677532	17850
Prestressed concrete beam element bridge	2566149	17108

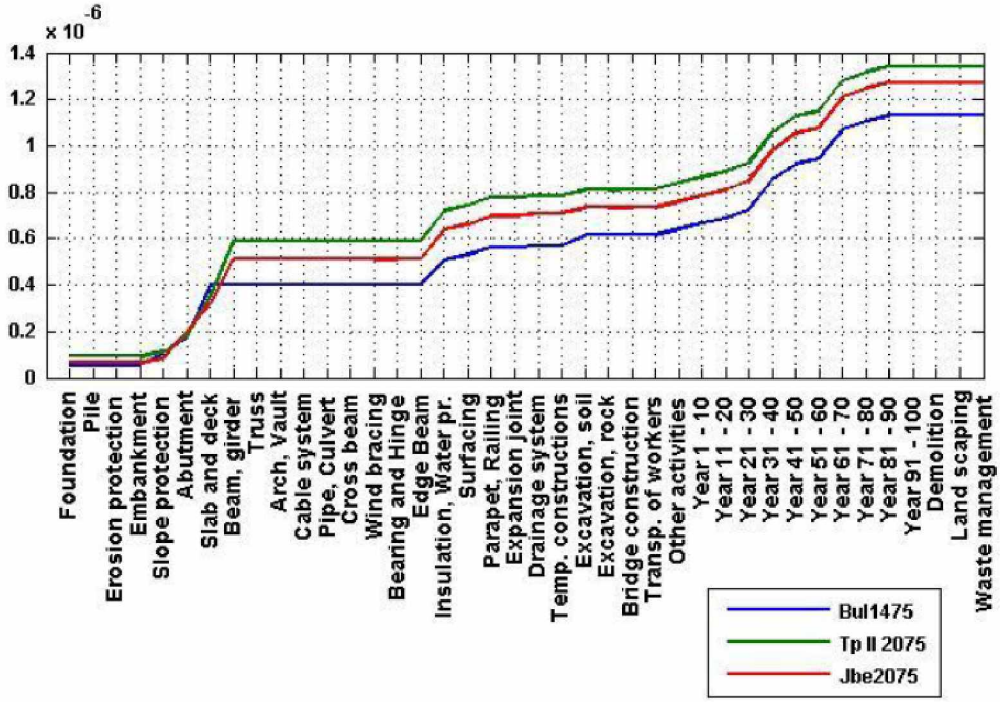

Figure 4. *Weighted environmental impact of standard bridges. A printout of BridgeLCA.*

Figure 5 represents the global warming potential of compared standard bridges without weighting.

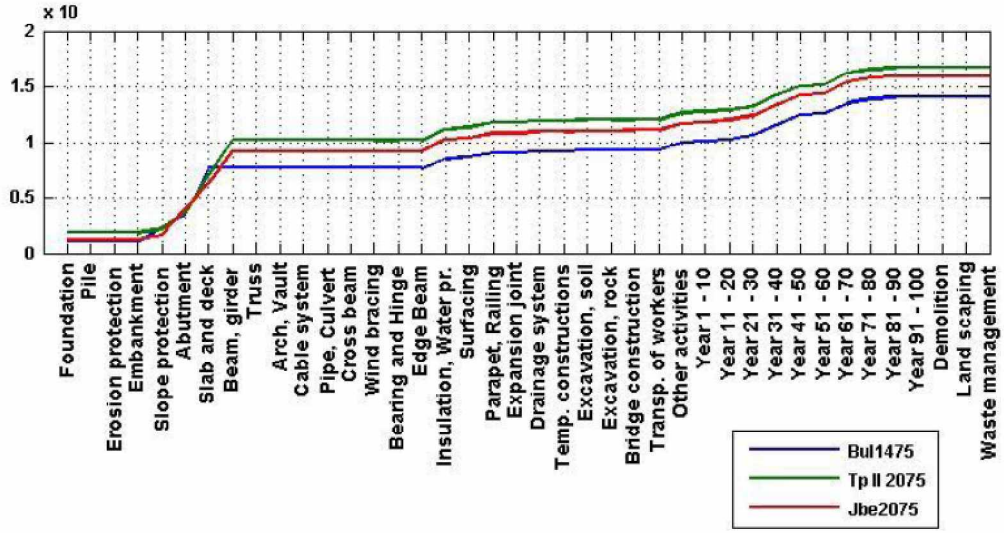

Figure 5. *The global warming potential of standard bridges in equivalent emissions of CO2. A printout of BridgeLCA program.*

5.1 Steel reinforced concrete cantilever slab bridge

Environmental impacts of steel reinforced concrete cantilever slab bridge are mainly composed of used concrete, reinforcing steel, asphalt and rubberized bitumen compound. The distribution of environmental materials between construction materials is represented in table 3. Table 4 represents distribution between bridge parts and construction phase.

Table 3. Environmental impacts of steel reinforced concrete cantilever slab bridge divided between construction materials.

	ADP kg Sb eq	AP kg SO_2 eq	EP kg PO_4 eq	GWP kg CO_2 eq	ODP kg CFC-11 eq	POCP kg C_2H_4 eq
Concrete	154,88	116,17	18,37	71248,27	0,00235	4,29
Structural steel	0,00	0,00	0,00	0,00	0,00000	0,00
Stainless steel	8,38	5,78	0,67	1122,22	0,00005	0,37
Reinforcing steel	157,92	68,88	12,21	18616,55	0,00110	8,15
Steel, lower grade	65,71	27,44	5,28	7698,70	0,00036	3,87
Formwork, timber	4,57	3,81	0,90	636,63	0,00007	0,19
Stone	8,12	122,06	29,47	1598,77	0,00012	1,20
Rubber	0,19	0,05	0,00	13,08	0,00000	0,00
Asphalt	593,03	67,91	9,79	16001,71	0,01740	5,69
Mastic	0,54	0,13	0,01	12,78	0,00001	0,01
Membrane	491,54	123,23	12,83	22308,32	0,00805	6,82
Epoxy	4,05	2,67	0,34	383,67	0,00005	0,10
Polyurethane	0,94	0,53	0,12	78,46	0,00002	0,03
Zinc coating	5,11	6,35	0,48	698,09	0,00011	0,24
TOTAL	1494,99	545,01	90,47	140417,25	0,02968	30,95

Table 4. Environmental impacts per bridge parts and construction phase.

	ADP kg Sb eq	AP kg SO_2 eq	EP kg PO_4 eq	GWP kg CO_2 eq	ODP kg CFC-11 eq	POCP kg C_2H_4 eq
Foundation	59,00	40,00	6,50	23 000,00	0,00079	1,90
Substructure	42,00	25,00	4,10	12 000,00	0,00047	1,60
Superstructure	190,00	100,00	17,00	42 000,00	0,00180	8,20
Equipment	290,00	73,00	9,10	15 000,00	0,00520	5,40
Construction	23,00	130,00	31,00	7 800,00	0,00034	1,60
Reparation and maintenance	900,00	170,00	22,00	41 000,00	0,02100	12,00
TOTAL	1 504,00	538,00	89,70	140 800,00	0,02960	30,70

5.2 Steel reinforced concrete deck composite bridge

Environmental impacts of steel reinforced concrete deck composite bridge are mainly composed of used concrete, structural steel, asphalt and rubberized bitumen compound. The distribution of environmental materials between construction materials is represented in table 5. Table 6 represents distribution between bridge parts and construction phase.

Table 5. Environmental impacts of steel reinforced concrete deck composite bridge divided between construction materials.

	ADP kg Sb eq	AP kg SO_2 eq	EP kg PO_4 eq	GWP kg CO_2 eq	ODP kg CFC-11 eq	POCP kg C_2H_4 eq
Concrete	152,01	114,01	18,03	69925,39	0,00230	4,21
Structural steel	250,12	120,12	21,85	29159,13	0,00116	14,60
Stainless steel	8,38	5,78	0,67	1122,22	0,00005	0,37
Reinforcing steel	98,99	43,18	7,65	11669,65	0,00069	5,11
Steel, lower grade	73,00	30,48	5,86	8553,05	0,00040	4,30
Formwork, timber	5,09	4,24	1,00	708,84	0,00008	0,21
Stone	4,61	69,19	16,71	906,33	0,00007	0,68
Rubber	1,27	0,35	0,03	86,38	0,00002	0,02
Asphalt	622,06	71,24	10,27	16785,01	0,01826	5,97
Mastic	0,13	0,03	0,00	3,14	0,00000	0,00
Membrane	540,25	135,44	14,10	24519,06	0,00885	7,50
Epoxy	4,25	2,80	0,36	402,45	0,00005	0,11
Polyurethane	6,67	3,79	0,86	557,46	0,00011	0,19
Zinc coating	15,73	19,55	1,48	2149,38	0,00033	0,74
TOTAL	1782,56	620,20	98,87	166547,47	0,03237	43,99

Table 6. Environmental impacts per bridge parts and construction phase.

	ADP kg Sb eq	AP kg SO_2 eq	EP kg PO_4 eq	GWP kg CO_2 eq	ODP kg CFC-11 eq	POCP kg C_2H_4 eq
Foundation	70,00	44,00	7,20	23 000,00	0,00083	2,60
Substructure	43,00	26,00	4,30	14 000,00	0,00050	1,60
Superstructure	380,00	200,00	35,00	65 000,00	0,00270	20,00
Equipment	340,00	86,00	11,00	17 000,00	0,00610	6,30
Construction	20,00	81,00	19,00	7 200,00	0,00030	1,10
Reparation and maintenance	930,00	180,00	23,00	40 000,00	0,02200	13,00
TOTAL	1 783,00	617,00	99,50	166 200,00	0,03243	44,60

5.3 Presressed concrete beam element bridge

Environmental impacts of prestressed concrete beam element bridge are mainly composed of used concrete, reinforcement steel, asphalt and rubberized bitumen compound. The distribution of environmental materials between construction materials is represented in table 7. Table 8 represents distribution between bridge parts and construction phase.

Table 7. Environmental impacts of prestressed concrete beam element bridge divided between construction materials.

	ADP kg Sb eq	AP kg SO_2 eq	EP kg PO_4 eq	GWP kg CO_2 eq	ODP kg CFC-11 eq	POCP kg C_2H_4 eq
Concrete	157,03	117,78	18,62	72237,83	0,00238	4,35
Structural steel	0,00	0,00	0,00	0,00	0,00000	0,00
Stainless steel	148,02	102,17	11,85	19825,92	0,00084	6,51
Reinforcing steel	119,52	52,13	9,24	14090,11	0,00083	6,17
Steel, lower grade	75,62	31,58	6,07	8860,23	0,00041	4,45
Formwork, timber	7,02	5,85	1,38	978,14	0,00011	0,29
Stone	4,61	69,19	16,71	906,33	0,00007	0,68
Rubber	2,18	0,60	0,05	148,67	0,00004	0,03
Asphalt	622,06	71,24	10,27	16785,01	0,01826	5,97
Mastic	0,14	0,03	0,00	3,36	0,00000	0,00
Membrane	540,25	135,44	14,10	24519,06	0,00885	7,50
Epoxy	4,25	2,80	0,36	402,45	0,00005	0,11
Polyurethane	1,05	0,60	0,14	88,09	0,00002	0,03
Zinc coating	5,74	7,13	0,54	783,82	0,00012	0,27
TOTAL	1687,50	596,54	89,33	159629,01	0,03197	36,35

Table 8. Environmental impacts per bridge parts and construction phase.

	ADP kg Sb eq	AP kg SO_2 eq	EP kg PO_4 eq	GWP kg CO_2 eq	ODP kg CFC-11 eq	POCP kg C_2H_4 eq
Foundation	51,00	32,00	5,30	17 000,00	0,00062	1,90
Substructure	72,00	45,00	7,30	23 000,00	0,00084	2,70
Superstructure	270,00	170,00	24,00	52 000,00	0,00220	11,00
Equipment	340,00	87,00	11,00	18 000,00	0,00610	6,40
Construction	20,00	81,00	19,00	7 200,00	0,00030	1,10
Reparation and maintenance	940,00	180,00	24,00	43 000,00	0,02200	13,00
TOTAL	1 693,00	595,00	90,60	160 200,00	0,03206	36,10

6 Conclusions

6.1 Life cycle costs

In bridge life cycle cost comparison, overall cost and price per bridge deck square meter were compared. The overall cost of steel reinforced concrete cantilever slab bridge is 239 000 € and price per deck square meter is 1680 €/m². The overall cost of steel reinforced concrete deck composite bridge is 305 000 € and price per deck square meter is 2030 €/m². The overall cost of prestressed concrete beam element bridge is 284 000 € and price per bridge square meter is 1890 €/m². Table 9 represents the life cycle cost comparison of standard bridges.

Table 9. The life cycle costs of standard bridges.

Life cycle costs [€]	Total cost	Per deck square meter
Steel reinforced concrete cantilever slab bridge	236 000	1660
Steel reinforced concrete deck composite bridge	299 000	1990
Prestressed concrete beam element bridge	279 000	1860

The most inexpensive bridge is of steel reinforced concrete cantilever slab bridge, the second inexpensive bridge is prestressed concrete beam element bridges and the most expensive bridge of compared standard types is steel reinforced concrete deck composite bridge. Although, the span length of steel reinforced concrete cantilever slab bridge is shorter than in other two compared bridge. Therefore, the overall cost is also lower.

The calculated prices for bridge deck square meter are not directly comparable for bridges with different length and width. For longer bridge length, the steel reinforced concrete cantilever slab bridge would not have such vantage. Moreover, concrete deck steel beam composite bridge would be more economical in longer span lengths. In addition, multi-span bridges were not taken into account in bridge life cycle costs.
In bridge life cycle cost comparison, all possible maintenance and repair actions were not taken into account. On the contrary, predictable and notable actions were taken into account.

Bridge demolition costs were estimated to be 10 % of bridge overall costs. The estimate is not precise for every compared standard bridge types. However, due to discounted values, the effect of demolition cost is minor thus making the margin of error insignificant.

6.2 Life cycle impacts

The compared standard bridges are almost the same lengthy and their purpose of use is same. Therefore, these standard bridges are suitable for life cycle assessment. Although, the steel reinforced concrete cantilever slab bridge is one meter shorter

than other two bridges, which benefit the comparison for that. Table 10 represents the environmental impacts per deck square meter.

Table 10. Environmental impacts of standard bridges per deck square meter.

Environmental impact per bridge deck square meter	ADP kg Sb eq	AP kg SO_2 eq	EP kg PO_4 eq	GWP kg CO_2 eq	ODP kg CFC-11 eq	POCP kg C_2H_4 eq
Cantilever slab bridge	10,4911825	3,82461657	0,634881	985,3842	0,000208292	0,2172116
Composite bridge	11,8837254	4,13467772	0,659116	1110,316	0,000215794	0,2932564
Prestressed bridge	11,2500244	3,9769304	0,595538	1064,193	0,000213165	0,2423228

In comparison, the steel reinforced concrete cantilever slab bridge prove to be most environmentally friendly bridge, the next is prestressed concrete beam element bridge and the least environmentally friendly is steel reinforced concrete deck composite bridge. Because all of the compared bridges are small, are the environmental impacts respectively small thus making the LCA comparison for bridges insignificant. However, for multiple bridges, the LCA comparison could be sensible.

In LCA comparison, it is need to taken into account, that the span length of steel reinforced concrete cantilever slab bridge is just 14 meter, where for other two standard bridge the span length is longer. That is why the cantilever bridge has benefit against two other compared bridges. However, the lengths of the decks are nearly the same, for which makes the comparison suitable.

The values of environmental impacts are not significant for small standard bridges with current emission costs. The used estimation value per carbon dioxide is 20 €/ton. The calculated values for standard bridges are

- 2 800 € for steel reinforced concrete cantilever slab bridge
- 3 400 € for steel reinforced concrete deck composite bridge
- 3 200 € for prestressed concrete beam element bridge.

Margin of cost between first and second alternative is only 600 €. As a conclusion, calculated emission costs are insignificant for smaller bridges with current emission costs. However, the importance of environmental impacts could be significant with weighting for environmental impact values.

7 Summary

Life cycle optimisation for standard bridges is a method to optimise the economical and environmentally friendly solution for choosing the best bridge type alternative. When optimising the bridge types, the esthetical value of bridges should not be ignored.

Life cycle analyse consisted of comparing three standard bridges: steel reinforced concrete cantilever slab bridge, concrete deck composite bridge and prestressed concrete beam element bridge. The most economical solution of compared bridges proved to be steel reinforced concrete cantilever slab bridge and the second economical is prestressed concrete beam element bridge. The concrete deck composite bridge proved to be most expensive.

The most environmentally friendly bridge proved to be steel reinforced concrete cantilever slab bridge, and the second environmentally friendly bridge is prestressed concrete beam element bridge. The least environmentally solution is concrete deck composite bridge.

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The cost estimate of steel reinforced concrete cantilever slab bridge

Number	Title	Unit	Amount	Unit price	Cost €
1620	EXCAVATIONS				
1624	Building and bridge pit				
1624.1	Excavation without supporting	m3ktr	822	5	3781
1810	BENCHES				
1811.1	Terraces on soil	m3rtr	200	9	1840
1830	PIT FILLINGS				
1830.1-5	Pit fillings, all included	m3rtr	600	11	6600
2140	SURFACING AND SURFACE STRUCTURES				
2143.1	Concrete stone revetment	m2tr	116	37	4292
2320	TURF AND MEADOW COVERING				
2321	Turfes				
2321.1	Seeded grassland	m2tr	88	4	326
4000	STRUCTURAL COMPONENTS				
4200	BRIDGES				
4207	Bridge base slab				
	1. Formwork and scaffolding	m2ktr	48	44	2112
	2. Reinforcement				
	*steel A500 HW	kg	1440	1	1339
	4.Concrete	m3rtr			
	*concrete K30-2	m3rtr	36	93	3334
4210	BRIDGE SUPPORTING STRUCTURE				
4211	Abutments				
4211.1	Concrete structures in abutments				
	1. Formwork and scaffolding				
	-formwork and scaffolding	m2tr	61	57	3477
	2. Reinforcement				
	*steel A500 HW	kg	1903	1	2093
	4.Concrete				
	*Concrete K35	m3rtr	32	101	3216
	*additional price P30	m3rtr	32	19	608
4212	Intermediate supports				
4212.1	Concrete structures in intermediate supports				

Number	Title	Unit	Amount	Unit price	Cost €
	1. Formwork and scaffolding				
	-formwork and scaffolding	m2tr	38	57	2181
	-formwork canvas	m2tr	23	11	253
	2. Reinforcement				
	*steel A500 HW	kg	536	1	590
	4.Concrete				
	*Concrete K35	m3rtr	7	101	673
	*additional price P30	m3rtr	7	19	127
4213.1	Ground supported concrete surface damp-proofing				
	-double rubberized bitumen brushing	m2tr	38	6	206
4220	BRIDGE SUPERSTRUCTURE				
4221	Concrete superstructures				
	1. Formwork and scaffolding				
	-formwork and scaffolding	m2tr	189	38	7182
	-formwork canvas	m2tr	180	11	1980
	2. Reinforcement				
	*steel A500 HW	kg	15591	1	14500
	4.Concrete				
	*Concrete K35	m3rtr	92	100	9200
	*additional price P30	m3rtr	92	19	1748
	*concrete K40	m3rtr	9	108	969
	*additional price P50	m3rtr	9	26	234
4230	BRIDGE DECK SURFACE STRUCTURES				
4231	Isolation				
4231.1	Sand blasting of isolation base	kan-m2	143	4	527
4231.2	Epoxy sealing	m2tr	143	19	2708
4231.3	Membrane covering				
	-asphalt mastic covering (double)	kan-m2	148	14	2072
4231.7	Edge beam inner surfare rubberized bitumen brushing	m2tr	19	5	87
4232	Protection of isolation				
4232.1	Protective layer of asphalt concrete				
	-AB6/50	kan-m2	143	5	656

Number	Title	Unit	Amount	Unit price	Cost €
4233.11	Asphalt concrete (AB)				
	-AB 11/70	m2tr	143	5	656
	-AB 20/120	m2tr	143	6	855
4240	BRIDGE EQUIPMENT				
4241.3	Joint sealings				
	-rubberized bitumen based joint sealings	mtr	38	5	175
4244	Transition slab				
4244.1	Cast-in situ transition slabs	m3rtr	23	275	6188
4245.12	Steel railing				
	-open railing (H2)	mtr	24	99	2376
	-open railing and high safety net (H2)	mtr	24	106	2544
	-skew heads (4m)	kpl	4	368	1472
4248.1	Dribble pipes	kpl	16	19	304
4248.2	Surface water pipes				
4248.21	Surface water pipes of the deck	kpl	4	187	748
4248.52	Surface water drainage with outlet and pipes	kpl	4	648	2592
4249.1	Charging place, pipes and fasteners				
	-PEH-plastic pipes di=400	mtr	2	74	148
5000	PROJECT TASKS				
5520	SCAFFOLDINGS				
	3. Bridge superstructure scaffolding				
	-cast-in situ bridge scaffolding viaduct	kan-m2	158	43	6781
	SUMMARY (VAT 0 %, index 2000=100)				
	Foundation + pintatyöt				16839
	Foundation slabs				6785
	Abutments				9394
	Intermediate supports				4030
	Superstructure				50154
	Bridge equipment				16546
	Total				103748

	BRIDGE COSTS				
	-titels				103748
	-construction site common costs 25 %				25937
	Total (i=100,0)				129685
	-index change of the costs				17624
	Bridge costs (i=135,9)				147309
	Bridge total costs (i=135,9)				147309
	-rounding				147000
	BRIDGE TOTAL COST (VAT 0 %, i=135,9)				147000
	Square price (i=135,9)				784
	Cost per area A, where A = total length x effective width				

The cost estimate of concrete deck composite bridge

Number	Title	Unit	Amount	Unit price	Cost €
1620	EXCAVATIONS				
1624	Building and bridge pit				
1624.1	Excavation without supporting	m3ktr	500	5	2300
1810	BENCHES				
1811.1	Terraces on soil	m3rtr	200	9	1840
1830	PIT FILLINGS				
1830.1-5	Pit fillings, all included	m3rtr	400	11	4400
2140	SURFACING AND SURFACE STRUCTURES				
2143.1	Concrete stone revetment	m2tr	39	37	1431
2320	TURF AND MEADOW COVERING				
2321	Turfes				
2321.1	Seeded grassland	m2tr	88	4	326
4000	STRUCTURAL COMPONENTS				
4200	BRIDGES				
4207	Bridge base slab				
	1. Formwork and scaffolding	m2ktr	44	44	1948
	2. Reinforcement				
	*steel A500HW	kg	3488	1	3244
	4.Concrete				
	*concrete K30-2	m3rtr	58	93	5384
4210	BRIDGE SUPPORTING STRUCTURE				
4211	Abutments				
4211.1	Concrete structures in abutments				
	1. Formwork and scaffolding				
	-formwork and scaffolding	m2tr	164	57	9348
	2. Reinforcement				
	*steel A500HW	kg	2200	1	2420
	4.Concrete				
	*Concrete K35	m3rtr	44	101	4422
	*additional price P30	m3rtr	4	19	76

Number	Title	Unit	Amount	Unit price	Cost €
4213.1	Ground supported concrete surface damp-proofing				
	-double rubberized bitumen brushing	m2tr	38	6	209
4220	SILLAN PÄÄLLYSRAKENNE				
4221	Concrete superstructures				
	1. Formwork and scaffolding				
	-formwork and scaffolding	m2tr	191	52	9911
	-formwork canvas	m2tr	140	11	1540
	2. Reinforcement				
	*steel A500HW	kg	6492	0,93	6038
	4. Concrete				
	*concrete K40	m3rtr	45	108	4814
	*additional price P30	m3rtr	7	19	142
4223	Steel superstructures				
	-single span beam bridges	kg	16320	1,6	26112
4230	BRIDGE DECK SURFACE STRUCTURES				
4231	Isolation				
4231.1	Sand blasting of isolation base	kan-m2	150	4	555
4231.2	Epoxy sealing	m2tr	150	19	2850
4231.3	Membrane covering				
	-asphalt mastic covering (double)	kan-m2	150	14	2100
4231.7	Edge beam inner surfare rubberized bitumen brushing	m2tr	14	5	64
4232	Protection of isolation				
4232.1	Protective layer of asphalt concrete				
	-AB6/50	kan-m2	150	5	690
4233.11	Asphalt concrete (AB)				
	-AB11/70	m2tr	150	5	690
	-AB20/120	m2tr	150	6	900
4240	BRIDGE EQUIPMENT				
4241	Expansion joint				
4241.4	Joint sealing				
	-elastic joint sealing	mtr	17	12	199

Number	Title	Unit	Amount	Unit price	Cost €
4242	Bearing and hinge				
4242.1	Bearings				
4242.11	Laminated rubber bearing -height < 60 mm Bearing volume 1,0 dm3	kpl	4	57	228
4241.3	Joint sealing -rubberized bitumen based joint sealings	mtr	40	5	184
4244	Transition slabs				
4244.1	Cast-in situ transition slab	m3rtr	23	275	6325
4245.12	Steel railings				
	-open railing (H2)	mtr	32	99	3168
	-open railing and high safety net (H2)	mtr	24	106	2544
	-skew heads (4m)	kpl	4	368	1472
4248.1	Dribble pipes	kpl	16	19	304
4248.2	Surface water pipes				
4248.21	Surface water pipes of the deck	kpl	4	187	748
4248.52	Surface water drainage with outlet and pipes	kpl	4	648	2592
4249.1	Charging place, pipes and fasteners -PEH-plastic pipes di=400	mtr	2	74	148
	SUMMARY (VAT 0 %, index 2000=100)				
	Foundation + pintatyöt				10296
	Foundation slabs				10576
	Abutments				16475
	Superstructure				56406
	Bridge equipment				17912
	Total				111666
	BRIDGE COSTS				
	-titels				111666
	-construction site common costs 25 %				27917
	Total (i=100,0)				139583
	-index change of the costs				18969
	Bridge costs (i=135,9)				158552

	Bridge total costs (i=135,9)				158552
	-rounding				448
	BRIDGE TOTAL COST (VAT 0 %, i=135,9)				159000
	Square price (i=135,9)				768
	Cost per area A, where A= total length x effective width				

The cost estimate of prestressed concrete beam element bridge

Number	Title	Unit	Amount	Unit price	Cost €
1620	EXCAVATIONS				
1624	Building and bridge pit				
1624.1	Excavation without supporting	m3ktr	500	5	2300
1810	BENCHES				
1811.1	Terraces on soil	m3rtr	200	9	1840
1830	PIT FILLINGS				
1830.1-5	Pit fillings, all included	m3rtr	400	11	4400
2140	SURFACING AND SURFACE STRUCTURES				
2143.1	Concrete stone revetment	m2tr	39	37	1443
2320	TURF AND MEADOW COVERING				
2321	Turfes				
2321.1	Seeded grassland	m2tr	88	4	326
4000	STRUCTURAL COMPONENTS				
4200	BRIDGES				
4207	Bridge base slab				
	1. Formwork and scaffolding	m2ktr	36	44	1591
	2. Reinforcement				
	*steel A500HW	kg	2390	1	2223
	4.Concrete				
	*concrete K30-2	m3rtr	40	93	3689
4210	BRIDGE SUPPORTING STRUCTURE				
4211	Abutments				
4211.1	Concrete structures in abutments				
	1. Formwork and scaffolding				
	-formwork and scaffolding	m2tr	189	57	10789
	2. Reinforcement				
	*steel A500HW	kg	3716	1	4087
	4.Concrete				
	*Concrete K35	m3rtr	74	101	7468
	*additional price P30	m3rtr	4	19	76
4213.1	Ground supported concrete surface damp-proofing				
	-double rubberized bitumen brushing	m2tr	38	6	209

Number	Title	Unit	Amount	Unit price	Cost €
4220	SILLAN PÄÄLLYSRAKENNE				
4221	Concrete superstructures				
	1. Formwork and scaffolding				
	-formwork and scaffolding	m2tr	199	46	9154
	-formwork canvas	m2tr	130	11	1430
	2. Reinforcement				
	*steel A500HW	kg	6494	0,93	6040
	4. Concrete				
	*concrete K40	m3rtr	66	108	7102
	*additional price P30	m3rtr	10	19	198
4222	Concrete element superstructures				
	2. Prestressed concrete elements	m3ktr	28,8	623	17942,4
	Reinforcement	kg	2120		
	formwork area	m2	159		
	Prestressing steel	kg	3600		
4230	BRIDGE DECK SURFACE STRUCTURES				
4231	Isolation				
4231.1	Sand blasting of isolation base	kan-m2	150	4	555
4231.2	Epoxysealing	m2tr	150	19	2850
4231.3	Membrane covering				
	-asphalt mastic covering (double)	kan-m2	150	14	2100
4231.7	Edge beam inner surfare rubberized bitumen brushing	m2tr	15	5	69
4232	Protection of isolation				
4232.1	Protective layer of asphalt concrete				
	-AB6/50	kan-m2	150	5	690
4233.11	Asphalt concrete (AB)				
	-AB11/70	m2tr	150	5	690
	-AB20/120	m2tr	150	6	900
4240	BRIDGE EQUIPMENT				
4241	Expansion joint				

Number	Title	Unit	Amount	Unit price	Cost €
4241.4	Joint sealing				
	-elastic joint sealing	mtr	17	12	199
4242	Bearing and hinge				
4242.1	Bearings				
4242.11	Laminated rubber bearing				
	-height < 60 mm				
	Bearing volume 1,0 dm3	kpl	8	57	456
4241.3	Joint sealing				
	-rubberized bitumen based joint sealings	mtr	40	5	184
4244	Transition slabs				
4244.1	Cast-in situ transition slab	m3rtr	23	275	6325
4245.12	Steel railings				
	-open railing (H2)	mtr	34	99	3366
	-open railing and high safety net (H2)	mtr	24	106	2544
	-skew heads (4m)	kpl	4	368	1472
4248.1	Dribble pipes	kpl	16	19	304
4248.2	Surface water pipes				
4248.21	Surface water pipes of the deck	kpl	4	187	748
4248.52	Surface water drainage with outlet and pipes	kpl	4	648	2592
4249.1	Charging place, pipes and fasteners				
	-PEH-plastic pipes di=400	mtr	2	74	148
	SUMMARY				
	(VAT 0%, index 2000=100)				
	Foundation + pintatyöt				10309
	Foundation slabs				7503
	Abutments				22629
	Superstructure				49720
	Bridge equipment				18338
	Total				108500
	BRIDGE COSTS				
	-titels				108500
	-construction site common costs 25 %				27125
	Total (i=100,0)				135624

	-index change of the costs				18431
	Bridge costs (i=135,9)				154056
	Bridge total costs (i=135,9)				154056
	-rounding				-56
	BRIDGE TOTAL COST (VAT 0% , i=135,9)				154000
	Square price (i=135,9)				689
	Cost per area A, where A = total length x effective width				

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