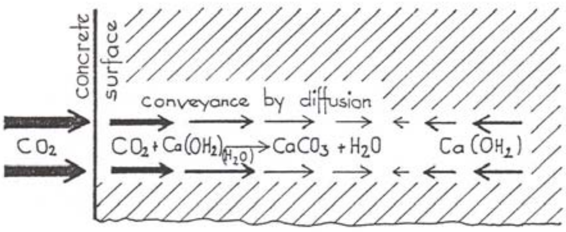
The Icelandic Building Research Institute
Rannsókarstofnun byggingariðnaðarins

Information on the use of concrete in Denmark, Sweden, Norway and Iceland

NI-project 03018

CO_2 Uptake During the Concrete Life Cycle



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PREFACE

The objective of this project, of which this report is a part, is to provide documentation of concrete carbonation during service life and secondary use. This documentation should be used for environmental assessment of concrete buildings and structures, and to evaluate the effect of concrete carbonation on the overall CO_2 emissions from cement and concrete production in the Nordic countries.

Approximately half of the CO_2 emission from cement production stems from the calcination of limestone, i.e. a process where limestone is burnt and CO_2 gas is released to the atmosphere. Theoretically, hardened concrete binds approximately the same amount of CO_2 in a process called carbonation. The concrete's ability to bind CO_2 and the rate of the process depends on many variables, including the type of concrete and its application.

The methodology and the impact that concrete carbonation has in the assessment of CO_2 emissions from concrete has not been fully documented. Specifically, there is a lack of knowledge about the carbonation of demolished and crushed concrete. The existing models for calculating carbonation do not take into account that the concrete is crushed and recycled after use. Consequently, the contribution of the cement and concrete industry to net CO_2 emissions is strongly overestimated. This overestimation has a significant influence on CO_2 policy; on the criteria for environmental labelling; and on the selection of materials based on principles of environmentally correct design. A comparison of the environmental impacts from different building materials (e.g. concrete versus wood and steel) is at present unfair because of the lack of documentation of the CO_2 uptake in concrete.

The present report is one of five documents published during the project "CO_2 uptake during the concrete life cycle". Three reports cover the background data and the last two reports include the results of the project.

The background reports are:

- Carbon dioxide uptake during concrete life cycle, state of the art, published by Swedish Cement and Concrete Research Institute - CBI, www.cbi.se, ISBN 91-976070-0-2
- Information on the use of concrete in Denmark, Sweden, Norway and Iceland, published by Icelandic Building Research Institute, www.ibri.is, ISBN 9979-9174-7-4
- Carbon dioxide uptake in demolished and crushed concrete, published by Norwegian Building Research Institute, www.byggforsk.no, ISBN 82-536-0900-0.

The reports with results are:

- Guidelines – Uptake of carbon dioxide in the life cycle inventory of concrete, published by Danish Technological Institute, www.teknologisk.dk, ISBN 87-7756-757-9
- The CO_2 balance of concrete in a life cycle perspective, published by Danish Technological Institute, www.teknologisk.dk, ISBN 87-7756-758-7

The participants in the project are:

Danish Technological Institute (Project Manager)
Aalborg Portland A/S (head of Steering Committee)
Norwegian Building Research Institute
Norcem A.S.
Elkem ASA Materials
Cementa AB
Swedish Cement and Concrete Research Institute
Icelandic Building Research Institute

Financing partners are:

Nordic Innovation Centre
Aalborg Portland A/S
Norcem A.S.
Cementa AB

The project was carried out from December 2003 to December 2005.

PREAMBLE

This report reveals the findings of task 2, a part of a more comprehensive program named Carbon Dioxide Uptake During Concrete Live Cycle, sponsored by the Nordic Innovation Center. Task 2 deals with concrete production in the participating countries, Denmark, Iceland, Norway and Sweden.

The report is mainly a data compilation concerning concrete production in these four countries. As the information available from each country is rather incoherent it has been quite hard to come to reliable findings in this report. The data had to be synchronized to fit the table frames, and to some extent, the figures given in the tables are educated guesses, based on available data. In particular it was difficult to forecast the concrete production in 2050. These estimates are probably conservative as minor increase (0-20 %) is assumed in comparison to production in 2003.

Yet, on the whole, the involved parties believe this report to give a reasonably accurate picture of the concrete production in the above-mentioned Nordic countries.

As the report contains only data, no conclusions are presented.

The leader for task 2 was Dr. Gísli Gudmundsson, Iceland, until 2004, when Guðni Jónsson took over. Other members in task 2 are Per Fidjestöl, Norway, Åsa Nilsson, Sweden and Caus Pade, Denmark, together they have supplied the data on which the findings rely. Special thanks are due to Dr. Knut Kjellsen, Norcem, for a substantial contribution to this work.

Reykjavík, December 2005

Dr. Ólafur H. Wallevik
Manager IBRI Rheocenter

Table of content

1 Introduction

The report presents tables of concrete production in four Nordic countries, Denmark, Sweden, Norway and Iceland. The three years which have been selected as representatives for the past, the present and the future are 1950, 2003 and 2050. Thus the information should give some idea of the development through a span of one hundred years.

The concrete production in each country is divided into three classes, Ready-Mix Concrete, Precast Elements and Precast Concrete Products. In addition, tables of production quantities in each strength class are presented, together with typical mix design. Also concrete strength classes for main building components are provided.

A wealth of information is needed to calculate the CO_2 uptake. The most important parameters are concrete quantity, cement type and quantity, wc-ratio, concrete strength class, the distribution of the use of the concrete in different parts of the building structure (walls, facades, slabs, columns, shallow core slabs, pavement, pipes etc.) and eventual coatings. This information is not readily available so the tables are to some extent based on estimates.

The main source of information was the ERMCO database on the statistics on ready mixed concrete, and information supplied by participants in the project from each country in question, based on local statistics from producers and associations. Nonetheless, part of the information needed in the project was difficult to obtain or not available at all. This regards both ready mix and precast concrete. In case of no data available, estimates based on personal judgement had to be done. Occasionally, information from one country was used as basis for estimation of analogous data in another country in lack of anything better.

2 Denmark

2.1 Ready-Mix Concrete (RMC)

Table 2.1 Denmark; RMC production and cement consumption

Year	Concrete production (mill m^3)	Cement consumption (mill tons)
1950	0,7[3]	0,17[3]
1965	0,89[1]	0,21[1]
1973	3,50[1]	0,83[1]
1982	1,65[1]	0,39[1]
1992	1,70[1]	0,40[1]
2002	2,3[2]	0,54[2]
2003	2,2[2]	0,53[2]
2050	2,86[3]	0,64[3]

Note: 1) to 3) refer to information sources, listed in section 2.5.

Table 2.2. Denmark; distribution of RMC on strength classes

Strength class	1950 (% of total production) [3]	2003 (% of total production) [2]	2050 (% of total production) [3]
< 15	20	10	5
15-25	45	45	40
25,5-35	30	40	40
>35	5	5	15

Note: 2) and 3) refer to information sources, listed in section 2.5.
Note: Concrete strength classified in concord with the ERMCO database.

Table 2.3. Denmark; Typical RMC mix design [3]

kg/m^3	1950: Typical mix design, SSD		2003: Typical mix design, SSD		2050: Typical mix design, SSD	
	C15-25	C25,5-35	C15-25	C25,5-35	C15-25	C25,5-35
Cement*	300	330	165[6]	240	180	190
Fly ash	0	0	80[6]	40	70	80
Microsilica	0	0	10[6]	12	20	24
Water	180	170	155[6]	155	155	145
Sand < 4mm	700	700	800[6]	700[6]	950	950
Stone > 4mm	1200	1200	1000[6]	1100	1050	1050
Cement type	CEM II/A-LL 52,5 R	CEM II/A-LL 52,5 R	CEM II/A-LL 52,5 R	CEM II/A-LL 52,5 R	CEM II/A-LL 52,5 R	CEM II/A-LL 52,5 R

Note: 3) and 6) refer to information sources, listed in section 2.5.
Note: Concrete strength classified in concord with the ERMCO database.

Table 2.4. Denmark; RMC, distribution of strength classes of building components [3)]

Production of total (%)	Average thickness of structure (mm)	1950		2003		2050	
		C15-25	C25,5-35	C15-25	C25,5-35	C15-25	C25,5-35
Foundations	*300*	90	10	0	100	0	100
Slabs	*200*	90	10	0	100	0	100
Walls	*200*	90	10	0	100	0	100

Note: 3) refers to information source, listed in section 2.4.
Note: Concrete strength classified in concord with the ERMCO database.

2.2 Denmark, usage and exposure table for RMC

Table 2.5 is based on data in tables 2.1-2.4. The data are weighted according to strength class and concrete usage. Weighting coefficients are given in table 2.6 and are settled by Dr. Knut Kjellsen (KK) and Dr. Ólafur Wallevik (OW).

Table 2.5. Denmark; production of ready mix concrete 1950, 2003 and estimation for 2050, divided on building components, environment and strength class

Production of concrete	Denmark	Average thickness of structure (mm)	1950			2003			2050		
			C15-20 (m^3)	C25-35 (m^3)	>C35 (m^3)	C15-20 (m^3)	C25-35 (m^3)	>C35 (m^3)	C15-20 (m^3)	C25-35 (m^3)	>C35 (m^3)
Walls	Indoor	180	175.500			326.700	237.600		237.600	267.300	
	Outdoor, sheltered	180	43.875			81.675	59.400		59.400	66.825	
	Outdoor	180	73.125			136.125	99.000		99.000	111.375	
Slabs	Indoor	200	182.000			338.800	246.400		246.400	277.200	
	Outdoor, sheltered	200	11.375			21.175	15.400		15.400	17.325	
	Outdoor	200	34.125			63.525	46.200		46.200	51.975	
Foundations	Buried	240	65.000			121.000	88.000		88.000	99.000	
	Wet	240	65.000			121.000	88.000		88.000	99.000	
Civil engineering structures	Outdoor, sheltered	400		60.000				22.000			66.000
	Outdoor	400		120.000				44.000			132.000
	Buried	400		60.000				22.000			66.000
	Wet	400		60.000				22.000			66.000

Table 2.6. Denmark; weighting coefficients used to generate table 2.5

	Strength class	1950 % of tot product ☐ Checl	2003 % of tot product) ☑ Chec	2050 % of tot product ☐ Chec	Year	Concrete product (mill m^3)	Cement consumpt (mill tons)
Data from PF, Elkem	<15-20	65%	55%	40%	1950	1	0,2
Data from ERMCO	25-35	30%	40%	45%	2003	2,2	0,53
Data estimted by IBRI	>35	5%	5%	15%	2050	2,2	0,53
Data estimted by OW & KK							

Percent concrete in:		Indoor	Outdoor sheltered	Outdoor	Burried	Wet	Total
Walls	45%	60%	15%	25%			100%
Slabs	35%	80%	5%	15%			100%
Foundations	20%				50%	50%	100%
Total	100%						
Civil Eng. Struct	100%		20%	40%	20%	20%	100%

2.3 Precast Element Concrete (PEC)

Table 2.7. Denmark; PEC production [4)]

Element type	1950			1968		
	Production (tons)	Concrete (m^3)	Production (m^2)	Production (tons)	Concrete (m^3)	Production (m^2)
Slabs, hollow core	0	0	0	340.606	141.919	1.124.000
Other slabs		Se note		0	0	0
Roof				47.798	19.916	174.000
Walls				297.767	124.070	768.000
Facades				246.259	102.608	545.000
Columns/Beams				115.000	47.917	
Other				52.000	21.667	

Element type	2003			2050		
	Production (tons)	Concrete (m^3)	Production (m^2)	Production (tons)	Concrete (m^3)	Production (m^2)
Slabs, hollow core	318.329	132.637	944.742	500.000	208.333	1.400.000
Other slabs	56.471	23.530	169.008	70.000	29.167	200.000
Roof	59.452	24.772	216.424	70.000	29.167	250.000
Walls	261.460	108.942	674.356	300.000	125.000	1.000.000
Facades	141.565	58.985	313.300	200.000	83.333	500.000
Columns/Beams	57.604	24.002		100.000	41.667	
Other	87.818	36.591		200.000	83.333	

Note: In 1950 the precast element production in Denmark had just started. The elements were usually cast at the building site. This applies also to ready-mix production, all concrete of that kind was mixed in situ. Accordingly, no information is available on production volumes in 1950. Not until in the late sixties, more or less reliable information on production volumes emerges. [1)]
Note: 1) and 4) refer to information sources, listed in section 2.5.

Table 2.8. Denmark; PEC exposure classes of building components [4)]

Element type	Exposure (indoor, outdoor, sheltered, underground, top side covered, back side painted, etc.)	Average thickness (mm)
Slabs, hollow core	Indoors only. Of the top surface, 80% is exposed, and 20% of the bottom surface. This corresponds to 20% of the top surface levelled with concrete and 80% of the bottom surface painted.	250mm
Other slabs	Indoors only. Of the top surface, 20% is exposed, and 20% of the bottom surface. This corresponds to 80% of the top surface levelled with concrete and 80% of the bottom surface painted.	250
Roof	Indoors only. Of the top surface, 50% is exposed, as the roofing materials are not CO_2 tight. Of the bottom surface, 20% is exposed as 80% is painted.	150
Walls	Indoors only. Of the top surface, 50% is exposed/untreated. The other side is completely painted.	150
Facades	There are four sides on a facade. Three of them are completely untreated, and 20% of the fourth.	70+150
Columns/Beams	There are four surfaces to each meter. One untreated surface corresponds to 25% of total surface	300 x 300
Other	Typically balconies. Totally untreated.	150

Note: 4) refers to information source, listed in section 2.5.

Table 2.9. Denmark; typical PEC mix design [4)]

Typical mix design - saturated surface dry

Element type	Cement (kg/m^3)	Fly ash (kg/m^3)	Microsilica (kg/m^3)	Water (kg/m^3)	Sand < 4mm (kg/m^3)	Stone > 4mm (kg/m^3)	Cement type
Slabs, hollow core	360	0	0	122	800	1160	CEM II/A LL 52,5R (IS/LA/<2)
Other slabs	360	0	0	150	785	1000	CEM II/A LL 52,5R (IS/LA/<2)
Roof	360	0	0	150	785	1000	CEM II/A LL 52,5R (IS/LA/<2)
Walls	340	0	0	150	785	1000	CEM II/A LL 52,5R (IS/LA/<2)
Facades	340	0	0	145	785	1000	CEM II/A LL 52,5R (IS/LA/<2)
Columns/Beams	360	0	0	150	785	1000	CEM II/A LL 52,5R (IS/LA/<2)
Other	360	0	0	145	785	1000	CEM II/A LL 52,5R (IS/LA/<2)

Note: 4) refers to information source, listed in section 2.5.

2.4 Precast Concrete Products (PCP)

Table 2.10. Denmark; PCP binder consumption, 1000 tons

Binder consumption (1000 tons)	1950 [3)]	2003 [5)]	2050 [3)]	1990 [5)]	2001 [5)]	2002 [5)]	2003 [5)]
Paving	270	270	270	120	260	246	270
Blocks	60	60	60	31	57	64	60
Elements	109	109	109	52	94	98	109
Pipes, etc.	24	24	24	54	22	27	24
Other (examples?)	35	35	35	26	32	32	35
Binder type*	A	B	B	A	B	B	B

* A=Pure Portland cement, B=Portland cement+other powder

Note: 3) and 5) refer to information sources, listed in section 2.5.

Table 2.11. Denmark; typical paving PCP mix design [3)]

Typical mix design - saturated surface dry

kg/m^3	Paving 1950	Paving 2003	Paving 2050
Cement	390	390	390
Fly ash	0	0	0
Microsilica	0	0	0
Water	160	160	160
SAND < 4mm	1500	1500	1500
STONE > 4mm	450	450	450
Cement type	CEM II/A-LL 42,5 R	CEM II/A-LL 42,5 R	CEM II/A-LL 42,5 R

Note: 3) refers to information source, listed in section 2.5.

Table 2.12. Denmark; PCP exposure classes

	Exposure (outdoor, indoor, underground, etc.)	Average thickness of product (mm)
Paving	outdoor 5)	60 5)
Blocks	underground 5)	80 3)
Elements	outdoor 5)	60 5)
Pipes, etc.		30 3)
Other (examples?)		

Note: 3) and 5) refer to information sources, listed in section 2.5.

2.5 Information sources for data from Denmark

Listed here are the sources on which the tables concerning concrete usage in Denmark rely.

1) Information from partners in the project from Denmark, compiled by Claus Pate
2) Information based on the ERMCO database [1]
3) Estimates based on judgements by personal at IBRI, (Guðni Jónsson, Hákon Ólafsson, Helgi Hauksson and Ólafur Wallevik)
4) Dansk Betonelementforening, "Medlemstatistik" from 1969 and [2] "Produktions-statistik", from 2003 and well as qualified guesses by Poul Erik Hjorth [3]
5) Based on statistics from the yearly assembly (2004, 1992, 1991) in "Dansk Beton Industriforening" (DBI) [4]
6) Corrections by Mette Glavind

3 Sweden

3.1 Ready-Mix Concrete (RMC)

Table 3.1. Sweden; RMC production and cement consumption

Year	Concrete Production (mill m³)	Cement consumption (mill tons)
1950	4,2[1)]	1,6[1)]
1965	7,0[1)]	2,2[1)]
1973	6,4[1)]	2,0[1)]
1982	3,8[1)]	1,2[1)]
1992	3,2[1)]	1,0[1)]
2002	3,2[1)]	1,0[1)]
2003	3,2[1)]	1,0 [1)]
2050	3,3[1)]	1,0[1)]

Note: 1) refers to information source, listed in section 3.5.

Table 3.2. Sweden; distribution of RMC on strength classes

Strength class	1950 (% of total production) [3)]	2001 (% of total production) [2)]	2050 (% of total production) [3)]
< 15	10	0	0
15-25	80	20	20
25,5-35	10	55	55
>35	0	25	25

Note: 2) and 3) refer to information sources, listed in section 3.5.
Note: Concrete strength classified in concord with the ERMCO database.

Table 3.3. Sweden; RMC mix design [3)]

kg/m³	1950: Typical mix design, SSD		2003: Typical mix design, SSD		2050: Typical mix design, SSD	
	C15-25	C25,5-35	C15-25	C25,5-35	C15-25	C25,5-35
Cement	330	380	280	340	220	270
Fly ash/BFS	0	0	0	0	30	40
Microsilica	0	0	0	0	0	10
Water	210	200	195	185	180	175
Sand < 4mm	700	700	900	900	950	950
Stone > 4mm	1200	1200	1100	1100	1050	1050
Cement type	CEM I 52,5 R	CEM I 52,5 R	CEM I 52,5 R	CEM I 52,5 R	CEM I 52,5 R	CEM I 52,5 R

Note: 3) refers to information source, listed in section 3.5.
Note: Concrete strength classified in concord with the ERMCO database.

Table 3.4. Sweden; RMC strength classes for building components

Production of total (%)	Average [1] thickness of structure (mm)	1950 [1]		2003 [1]		2050 [3]	
		C15-25	C25,5-35	C15-25	C25,5-35	C15-25	C25,5-35
Foundations	*800*	85	15	10	90	0	100
Slabs	*200*	85	15	10	90	0	100
Walls	*160*	85	15	10	90	0	100

Note: 1) and 3) refer to information sources, listed in section 3.5.
Note: Concrete strength classified in concord with the ERMCO database.

3.2 Sweden; usage and exposure for RMC

Table 3.5 is based on data in tables 3.1-3.4. The data are weighted according to strength class and concrete usage. Weighting coefficients are given in table 3.6 and are settled by Dr. Knut Kjellsen (KK) and Dr. Ólafur Wallevik (OW).

Table 3.5. Sweden; production of ready mix concrete 1950, 2003 and estimation for 2050, divided on building components, environment and strength class

Production of concrete	Sweden	Average thickness of structure (mm)	1950 C15-20 (m^3)	1950 C25-35 (m^3)	1950 >C35 (m^3)	2003 C15-20 (m^3)	2003 C25-35 (m^3)	2003 >C35 (m^3)	2050 C15-20 (m^3)	2050 C25-35 (m^3)	2050 >C35 (m^3)
Walls	Indoor	180	1.020.600			172.800	509.760		207.360	611.712	
	Outdoor, sheltered	180	255.150			43.200	127.440		51.840	152.928	
	Outdoor	180	425.250			72.000	212.400		86.400	254.880	
Slabs	Indoor	200	1.058.400			179.200	528.640		215.040	634.368	
	Outdoor, sheltered	200	66.150			11.200	33.040		13.440	39.648	
	Outdoor	200	198.450			33.600	99.120		40.320	118.944	
Foundations	Buried	240	378.000			64.000	188.800		76.800	226.560	
	Wet	240	378.000			64.000	188.800		76.800	226.560	
Civil engineering structures	Outdoor, sheltered	400		84.000				134.400			161.280
	Outdoor	400		168.000				268.800			322.560
	Buried	400		84.000				134.400			161.280
	Wet	400		84.000				134.400			161.280

Table 3.6. Sweden; weighting coefficients used to generate table 3.5

	Strength class	1950 (% of total production) ☑ Check	2003 (% of total production) ☑ Check	2050 (% of total production) ☑ Check	Year	Concrete Production (mill m^3)	Cement consumption (mill tons)
Data from PF, Elkem	<15-20	90%	20%	20%	1950	4,2	1,6
Data from ERMCO	25-35	10%	59%	59%	2003	3,2	1,04
Data estimted by IBRI	>35	0%	21%	21%	2050	3,84	1,14
Data estimted by OW & KK							

Percent concrete in:		Indoor	Outdoor sheltered	Outdoor	Burried	Wet	Total
Walls	45%	60%	15%	25%			100%
Slabs	35%	80%	5%	15%			100%
Foundations	20%				50%	50%	100%
Total	100%						
Civil Eng. Structu	100%		20%	40%	20%	20%	100%

3.3 Precast Element Concrete (PEC)

Table 3.7. Denmark; PEC production [3)]

Element type	1950			1968		
	Production (tons)	Concrete (m^3)	Production (m^2)	Production (tons)	Concrete (m^3)	Production (m^2)
Slabs, hollow core	0	0	0			
Other slabs	0	0	0			
Roof	0	0	0			
Walls	0	0	0			
Facades	0	0	0			
Columns/Beams	0	0	0			
Other	0	0	0			

Element type	2003			2050		
	Production (tons)	Concrete (m^3)	Production (m^2)	Production (tons)	Concrete (m^3)	Production (m^2)
Slabs, hollow core	424.208	176.753	1.363.886	424.208	176.753	1.363.886
Other slabs	75.254	31.356	243.990	75.254	31.356	243.990
Roof	85.828	35.762	312.443	85.828	35.762	312.443
Walls	362.361	150.984	973.541	362.361	150.984	973.541
Facades	196.197	81.749	452.299	196.197	81.749	452.299
Columns/Beams	76.764	31.985	159.924	76.764	31.985	159.924
Other	121.708	50.712		121.708	50.712	

Note: 3) refers to information source, listed in section 3.5.

Table 3.8. Sweden; PEC exposure classes of building components [3)]

Element type	Exposure (indoor, outdoor, sheltered, underground, top side covered, back side painted, etc.)	Average thickness (mm)
Slabs, hollow core	indoor (top side covered, backside painted)	350
Other slabs	?	200
Roof	outdoor	200
Walls	indoor	200
Facades	outdoor	200
Columns/Beams	outdoor/indoor	300
Other	outdoor/indoor	200

Note: 3) refers to information source, listed in section 3.5.

Table 3.9. Sweden; typical PEC mix design [1)]

Typical mix design - saturated surface dry

Element type	Cement (kg/m³)	Fly ash (kg/m³)	Microsilica (kg/m³)	Water (kg/m³)	Sand < 4mm (kg/m³)	Stone > 4mm (kg/m³)	Cement type
Slabs, hollow core							
Other slabs							
Roof							
Walls	400			145	775	1060	CEM II/A-LL 42,5 R
Facades	440			207	425	827	CEM II/A-LL 42,5 R
Columns/Beams	400			145	775	1060	CEM II/A-LL 42,5 R
Other							

Note: 1) refers to information source, listed in section 3.5.

3.4 Precast Concrete Products (PCP)

Table 3.10. Sweden; PCP binder consumption, 1000 tons

Binder consumption (1000 tons)	1950 [3)]	2003 [1)]	2050 [3)]	1990	2001 [1)]	2002 [1)]	2003 [1)]
Paving	81	81	81		68	66	81
Blocks	13	13	13		17	15	13
Elements							
Pipes, etc.	44	44	44		40	45	44
Other	38	38	38		46	45	38
Binder type*	A	B	B		A	B	B

* A=Pure Portland cement, B=Portland cement+other powder

Note: 1) and 3) refer to information sources, listed in section 3.5.

Table 3.11. Sweden; Typical paving PCP mix design, kg/m³

Typical mix design - saturated surface dry

kg/m³	Paving 1950 [3)]	Paving 2003 [1)]	Paving 2050 [3)]
Cement	390	390	390
Fly ash	0	0	0
Microsilica	0	0	0
Water	160	160	160
SAND < 4mm	1500	1500	1500
STONE > 4mm	450	450	450
Cement type	CEM II/A-LL 42,5 R	CEM II/A-LL 42,5 R	CEM II/A-LL 42,5 R

Note: 1) and 3) refer to information sources, listed in section 3.5.

Table 3.12. Sweden; PCP exposure classes

	Exposure (outdoor, indoor, underground, etc.) 1)	Average thickness of product (mm)
Paving	outdoor	80 1)
Blocks	underground	80 3)
Elements	outdoor	150 3)
Pipes, etc.	underground	30 1)
Other (examples?)		

Note: 1) and 3) refer to information sources, listed in section 3.5.

3.5 Information sources for data from Sweden

Listed here are the sources on which the tables concerning concrete usage in Sweden relies.

1) Information from partners in the project from Sweden, compiled by Åsa Nilsson
2) Information based on the ERMCO database [1]
3) Estimates based on judgements by personal at IBRI, (Guðni Jónsson, Hákon Ólafsson, Helgi Hauksson and Ólafur Wallevik).

4 Norway

4.1 Ready-Mix Concrete (RMC)

Table 4.1. Norway; RMC production and cement consumption

Year	Concrete Production (mill m^3)	Cement consumption (mill tons)
1950	1,2[2)]	0,4[2)]
1965		
1973		
1982		
1992		
2002		
2003	2,4[1)]	0,8[2)]
2050	2,4[3)]	0,8[3)]

Note: 1), 2) and 3) refer to information sources, listed in section 4.5.

Table 4.2. Norway; distribution of RMC on strength classes

Strength class	1950 (% of total production) [9)]	2003 (% of total production) [1)]	2050 (% of total production) [3)]
< 15	10	0	0
15-25	80	16	0
25,5-35	10	59	75
>35	0	26	25

Note: 1), 3) and 9) refer to information sources, listed in section 4.5.
Note: Concrete strength classified in concord with the ERMCO database.

Table 4.3. Norway; RMC mix design [3) 4)], kg/m^3

kg/m^3	1950: Typical mix design, SSD		2003: Typical mix design, SSD		2050: Typical mix design, SSD	
	C15-25	C25,5-35	C15-25	C25,5-35	C15-25	C25,5-35
Cement	330	380	270	290	240	260
Fly ash	0	0	0	0	0	0
Microsilica	0	0	0	10	0	15
Water	210	200	190	180	175	165
Sand < 4mm	800	800	900	900	950	950
Stone > 4mm	1050	1050	1000	1000	950	950
Cement type	CEM I 42,5 R	CEM I 42,5 R	CEM I 42,5 R	CEM I 42,5 R	CEM II 42,5 R	CEM II 42,5 R

Note: 3) and 4) refer to information sources, listed in section 4.5.
Note: Concrete strength classified in concord with the ERMCO database.

Table 4.4. Norway; RMC strength classes for building components [3) 4)]

Production of total (%)	Average thickness of structure (mm)	1950		2003		2050	
		C15-25	C25,5-35	C15-25	C25,5-35	C15-25	C25,5-35
Foundations	*800*	85	15	10	90	0	100
Slabs	*200*	85	15	10	90	0	100
Walls	*160*	85	15	10	90	0	100

Note: 3) and 4) refer to information sources, listed in section 4.5.
Note: Concrete strength classified in concord with the ERMCO database.

4.2 Norway; summary table for RMC

Table 4.5 is based on data in tables 4.1-4.4. The data are weighted according to strength class and concrete usage. Weighting coefficients are given in table 2.6 and are settled by Dr. Knut Kjellsen (KK) and Dr. Ólafur Wallevik (OW).

Table 4.5. Norway; production of ready mix concrete 1950, 2003 and estimation for 2050, divided on building components, environment and strength class [1) 2) 4) 5)]

Production of concrete	Norway	Average thickness of structure (mm)	1950 C15-20 (m^3)	1950 C25-35 (m^3)	1950 >C35 (m^3)	2003 C15-20 (m^3)	2003 C25-35 (m^3)	2003 >C35 (m^3)	2050 C15-20 (m^3)	2050 C25-35 (m^3)	2050 >C35 (m^3)
Walls	Indoor	180	291.600				486.000			486.000	
	Outdoor, sheltered	180	72.900				121.500			121.500	
	Outdoor	180	121.500				202.500			202.500	
Slabs	Indoor	200	302.400				504.000			504.000	
	Outdoor, sheltered	200	18.900				31.500			31.500	
	Outdoor	200	56.700				94.500			94.500	
Foundations	Burried	240	108.000				180.000			180.000	
	Wet	240	108.000				180.000			180.000	
Civil engineering structures	Outdoor, sheltered	400		24.000				120.000			120.000
	Outdoor	400		48.000				240.000			240.000
	Burried	400		24.000				120.000			120.000
	Wet	400		24.000				120.000			120.000

Note: 1), 2), 4) and 5) refer to information sources, listed in section 4.5.

Table 4.6: Norway; weighting coefficients used to generate table 4.5 [1) 2) 4) 5)]

Strength class	1950 (% of total production) Check	2003 (% of total production) Check	2050 (% of total production) Check
<15-20	90%	0%	0%
25-35	10%	80%	80%
>35	0%	20%	20%

Year	Concrete Production (mill m^3)	Cement consumption (mill tons)
1950	0,05	0,02
2003	0,25	0,08
2050	0,3	0,10

Percent concrete in:		Indoor	Outdoor sheltered	Outdoor	Burried	Wet	Total
Walls	45%	60%	15%	25%			100%
Slabs	35%	80%	5%	15%			100%
Foundations	20%				50%	50%	100%
Total	100%						
Civil Eng. Structu	100%		20%	40%	20%	20%	100%

Note: 1), 2), 4) and 5) refer to information sources, listed in section 4.5.

4.3 Precast Element Concrete (PEC)

Table 4.7. Norway; PEC production [3) 6) 7)]

Element type	1950			1968		
	Production (tons)	Concrete (m^3)	Production (m^2)	Production (tons)	Concrete (m^3)	Production (m^2)
Slabs, hollow core	0	0	0			
Other slabs		0				
Roof		0				
Walls		0				
Facades		0				
Columns/Beams		0				
Other		0				

Element type	2003			2050		
	Production (tons)	Concrete (m^3)	Production (m^2)	Production (tons)	Concrete (m^3)	Production (m^2)
Slabs, hollow core		195.000	1.144.500		195.000	1.144.500
Other slabs		14.021	116.845		14.021	116.845
Roof		0	0		0	0
Walls		34.266	155.756		34.266	155.756
Facades		38.209	195.944		38.209	195.944
Columns/Beams	67.075	27.947		67.075	27.947	
Other	19.165	7.985		19.165	7.985	

Note: 3), 6), and 7) refer to information sources, listed in section 4.5.

Table 4.8. Norway; PEC exposure classes of building components [4) 7) 8)]

Element type	Exposure (indoor, outdoor, sheltered, underground, top side covered, back side painted, etc.)	Average thickness (mm)
Slabs, hollow core	Indoors only. Of the top surface, 80% is exposed, and 20% of the bottom surface. This corresponds to 20% of the top surface levelled with concrete and 80% of the bottom surface painted.	300mm
Other slabs	Indoors only. Of the top surface, 20% is exposed, and 20% of the bottom surface. This corresponds to 80% of the top surface levelled with concrete and 80% of the bottom surface painted.	120
Roof	Indoors only. Of the top surface, 50% is exposed, as the roofing materials are not CO_2 tight. Of the bottom surface, 20% is exposed as 80% is painted.	120
Walls	Indoors only. Of the top surface, 50% is exposed/untreated. The other side is completely painted.	220
Facades	There are four sides on a facade. Three of them are completely untreated, and 20% of the fourth.	70+150
Columns/Beams	There are four surfaces to each meter. One untreated surface corresponds to 25% of total surface area.	300 x 300
Other	Typically balconies. Totally untreated.	150

Note: 4), 7), and 8) refer to information sources, listed in section 4.5.

Table 4.9. Norway; typical PEC mix design 7)

Typical mix design - saturated surface dry

Element type	Cement (kg/m^3)	Fly ash (kg/m^3)	Microsilica (kg/m^3)	Water (kg/m^3)	Sand < 4mm (kg/m^3)	Stone > 4mm (kg/m^3)	Cement type
Slabs, hollow core	320	0	0	135	850	1000	CEM I 42,5 RR
Other slabs	420	0	0	190	750	950	CEM I 42,5 RR
Roof	0	0	0	0	0	0	
Walls	350	0	0	175	750	1000	CEM I 42,5 RR
Facades	350	0	0	175	750	1000	CEM I 42,5 RR
Columns/Beams	420	0	0	190	750	950	CEM I 42,5 RR
Other	420	0	0	190	750	950	CEM I 42,5 RR

Note: 7) refers to information source, listed in section 4.5.

4.4 Precast Concrete Products (PCP)

Table 4.10. Norway; PCP binder consumption 2) 3)

Binder consumption (1000 tons)	1950	2003	2050	1990	2001	2002	2003
Paving	11	41	41				
Blocks	70	35	35				
Elements	10	21	21				
Pipes, etc.	40	60	60				
Other (examples?)	40	35	35				
Binder type	CEM I	CEM I	CEM II				

Note: 2) and 3) refer to information sources, listed in section 4.5.

Table 4.11. Norway; typical paving PCP mix design 3)

Typical mix design - saturated surface dry

kg/m^3	Paving 1950	Paving 2003	Paving 2050
Cement	390	390	350
Fly ash	0	0	0
Microsilica	0	0	0
Water	160	130	140
SAND < 4mm	1500	370	400
STONE > 4mm	450	1500	1500
Cement type	CEM I	CEM I	CEM II

Note: 3) refers to information source, listed in section 4.5.

Table 4.12. Norway; PCP exposure classes 3) 4) 5)

	Exposure (outdoor, indoor, underground, etc.)	Average thickness of product (mm)
Paving	outdoor	60
Blocks	underground	160
Elements	outdoor	120
Pipes, etc.	underground	60
Other (examples?)		

Note: 3), 4) and 5) refer to information sources, listed in section 4.5.

4.5 Information sources for data from Norway

Listed here are the sources on which the tables concerning concrete usage in Norway relies.

1) Based on statistics from the Norwegian Ready-Mixed Concrete Association (FABEKO) [6]
2) Based on sales statistics from Norcem A.S
3) Based on judgement by Mr. P. Fidjestøl (Elkem ASA) and Dr. K. O. Kjellsen (Norcem A.S)
4) Based on current knowledge and common practice
5) Based on judgment by Dr. O. H. Wallevik (Building Research Institute of Iceland) and Dr. K. O. Kjellsen (Norcem A.S)
6) Based on production statistics from the Norwegian Precast Concrete Federation (Betongelementforeningen) [7]
7) Based on communication with Mr. J-E. Reiersen (Norwegian Precast Concrete Federation)
8) Based on judgement by Dr. B. Lagerblad (Swedish Cement and Concrete Research Institute)
9) Estimates based on judgements by personal at IBRI (Guðni Jónsson, Hákon Ólafsson, Helgi Hauksson and Ólafur Wallevik)

5 Iceland

5.1 Ready- Mix Concrete (RMC)

Table 5.1. Iceland; RMC production and cement consumption [3)]

Year	Concrete production (mill m^3)	Cement consumption (mill tons)
1950	0,05	0,02
1965		
1973		
1982		
1992		
2002		
2003	0,25	0,1
2050	0,26	0,1

Note: 3) refers to information source, listed in section 5.5.

Table 5.2. Iceland; distribution of RMC on strength classes [3)]

Strength class	1950 (% of total production)	2003 (% of total production)	2050 (% of total production)
< 15	0	0	0
15-25	90	70	70
25,5-35	10	25	25
>35	0	5	5

Note: 3) refers to information source, listed in section 5.5.
Note: Concrete strength classified in concord with the ERMCO database.

Table 5.3. Iceland; RMC mix design [3)], kg/m^3

kg/m^3	1950: Typical mix design, SSD		2003: Typical mix design, SSD		2050: Typical mix design, SSD	
	C15-25	C25,5-35	C15-25	C25,5-35	C15-25	C25,5-35
Cement*	250	300	300	330	-	290
Fly ash	0	0	0	0	-	0
Microsilica	0	0	25	25	-	20
Water	160	150	190	180	-	165
Sand < 4mm	700	700	800	800	-	800
Stone > 4mm	1100	1100	100	1000	-	1000
Cement type	CEM I 52,5N	CEM I 52,5N	CEM I 52,5N	CEM I 52,5N	CEM I 52,5N	CEM I 52,5 N

Note: 3) refers to information source, listed in section 5.5.
Note: Concrete strength classified in concord with the ERMCO database.

Table 5.4. Iceland; RMC strength classes for building components [3)]

Production of total (%)	Average thickness of structure (mm)	1950		2003		2050	
		C15-25	C25,5-35	C15-25	C25,5-35	C15-25	C25,5-35
Foundations	*300*	100	0	90	10	90	10
Slabs	*200*	100	0	75	25	75	25
Walls	*200*	100	0	75	25	75	25

Note: 3) refers to information source, listed in section 5.5.
Note: Concrete strength classified in concord with the ERMCO database.

5.2 Iceland; summary table for RMC

Table 5.5 is based on data in tables 5.1-5.4. The data are weighted according to strength class and concrete usage. Weighting coefficients are given in table 2.6 and are settled by Dr. Knut Kjellsen (KK) and Dr. Ólafur Wallevik (OW).

Table 5.5. Iceland; production of ready mix concrete 1950, 2003 and estimation for 2050, divided on building components, environment and strength class

Production of concrete	Iceland	Average thickness of structure (mm)	1950			2003			2050		
			C15-20 (m^3)	C25-35 (m^3)	>C35 (m^3)	C15-20 (m^3)	C25-35 (m^3)	>C35 (m^3)	C15-20 (m^3)	C25-35 (m^3)	>C35 (m^3)
Walls	Indoor	180	12.150			0	54.000		0	64.800	
	Outdoor, sheltered	180	3.038			0	13.500		0	16.200	
	Outdoor	180	5.063			0	22.500		0	27.000	
Slabs	Indoor	200	12.600			0	56.000		0	67.200	
	Outdoor, sheltered	200	788			0	3.500		0	4.200	
	Outdoor	200	2.363			0	10.500		0	12.600	
Foundations	Burried	240	4.500			0	20.000		0	24.000	
	Wet	240	4.500			0	20.000		0	24.000	
Civil engineering structures	Outdoor, sheltered	400		1.000				10.000			12.000
	Outdoor	400		2.000				20.000			24.000
	Burried	400		1.000				10.000			12.000
	Wet	400		1.000				10.000			12.000

Table 5.6. Iceland; weighting coefficients used to generate table 4.5.

	Strength class	1950 % of tot producti Ched	2003 % of tot product Chec	2050 % of tot product Chec	Year	Concrete Product (mill m^3)	Cement consumpt (mill tons)
Data from PF, Elkem	<15-20	90%	0%	0%	1950	0,05	0,02
Data from ERMCO	25-35	10%	80%	80%	2003	0,25	0,08
Data estimted by IBRI	>35	0%	20%	20%	2050	0,3	0,10
Data estimted by OW & KK							

Percent concrete in:		Indoor	Outdoor sheltered	Outdoor	Burried	Wet	Total
Walls	45%	60%	15%	25%			100%
Slabs	35%	80%	5%	15%			100%
Foundations	20%				50%	50%	100%
Total	100%						
Civil Eng. Struct	100%		20%	40%	20%	20%	100%

5.3 Precast Element Concrete (PEC)

Table 5.7. Iceland; PEC production [3)]

Element type	1950			1968		
	Production (tons)	Concrete (m^3)	Production (m^2)	Production (tons)	Concrete (m^3)	Production (m^2)
Slabs, hollow core	0	0	0	-	-	-
Other slabs	0	0	0	-	-	-
Roof	0	0	0	-	-	-
Walls	0	0	0	-	-	-
Facades	0	0	0	-	-	-
Columns/Beams	0	0	0	-	-	-
Other	0	0	0	-	-	-

Element type	2003			2050		
	Production (tons)	Concrete (m^3)	Production (m^2)	Production (tons)	Concrete (m^3)	Production (m^2)
Slabs, hollow core	24.000	10.000	150.000	28.800	12.000	180.000
Other slabs	0	0	0	0	0	0
Roof	0	0	0	0	0	0
Walls	19.200	8.000	80.000	23.040	9.600	96.000
Facades	0	0	0	0	0	0
Columns/Beams	4.800	2.000	20.000	5.760	2.400	24.000
Other	1.200	500	5.000	1.440	600	6.000

Note: 3) refers to information source, listed in section 5.5.

Table 5.8. Iceland; PEC exposure classes of buildings components [3)]

Element type	Exposure (indoor, outdoor, sheltered, underground, top side covered, back side painted, etc.)	Average thickness (mm)
Slabs, hollow core	indoor	300
Other slabs	-	-
Roof	-	-
Walls	indoor/outdoor	200
Facades	-	-
Columns/Beams	indoor	300
Other	indoor/outdoor	200

Note: 3) refers to information source, listed in section 5.5.

Table 5.9. Iceland; typical PEC mix design [3)]

Typical mix design - saturated surface dry

Element type	Cement (kg/m^3)	Fly ash (kg/m^3)	Microsilica (kg/m^3)	Water (kg/m^3)	Sand < 4mm (kg/m^3)	Stone > 4mm (kg/m^3)	Cement type
Slabs, hollow core	350	0	18	140	800	1050	CEM I 52,5N
Other slabs	-	-	-	-	-	-	-
Roof	-	-	-	-	-	-	-
Walls	350	0	18	160	800	1050	CEM I 52,5N
Facades	-	-	-	-	-	-	-
Columns/Beams	350	0	18	160	800	1050	CEM I 52,5N
Other	350	0	18	160	800	1050	CEM I 52,5N

Note: 3) refers to information source, listed in section 5.5.

5.4 Precast Concrete Products (PCP)

Table 5.10. Iceland; PCP binder consumption [3)]

Binder consumption (1000 tons)	1950	2003	2050	1990	2001	2002	2003
Paving	0	20	24				
Blocks	0	20	24				
Elements	0	6	7				
Pipes, etc.	2	10	12				
Other (examples?)	0	0	0				
Binder type*	A	A/B	A/B				

* A=Pure Portland cement, B=Portland cement+other powder

Note: 3) refers to information source, listed in section 5.5.

Table 5.11. Iceland; typical paving PCP mix design [3)]

Typical mix design - saturated surface dry

kg/m^3	Paving 1950	Paving 2003	Paving 2050
Cement	-	380	380
Fly ash	-	-	-
Microsilica	-	8	8
Water	-	150	150
SAND < 4mm	-	1600	1600
STONE > 4mm	-	0	0
Cement type		CEM I 52,5N	CEM I 52,5N

Note: 3) refers to information source, listed in section 5.5.

Table 5.12. Iceland; PCP exposure classes [3)]

	Exposure (outdoor, indoor, underground, etc.)	Average thickness of product (mm)
Paving	outdoor	60
Blocks	outdoor	80
Elements	outdoor	150
Pipes, etc.	underground	40
Other (examples?)	-	-

5.5 Information source for data from Iceland

The source on which the tables concerning concrete usage in Iceland relies is:

[1)] Estimates based on judgements by personal at IBRI (Guðni Jónsson, Hákon Ólafsson, Helgi Hauksson and Ólafur Wallevik) partly based on personal communication with the largest concrete producers in Iceland, and the yearly cement consumption in Iceland.

6 Final remarks

The information in the report is to be used in later tasks in this project. As mentioned in chapter 1, some important data was difficult to obtain. Additionally, the data available from the participating countries were not always compatible in every way. Thus, assumptions had to made to certain extent, but these are based on educated guesses. This part of the data was however estimated by persons known to possess experience and knowledge regarding the information in question. Further, it should be stressed that the data for the year 2050 are generally prudent estimates.

No accuracy boundaries are stated for the figures presented in the report as such boundaries would be a mere guesses. However, the information appearing in the report is considered as precise as the data sources allow, and should be reliable enough to serve as a base for calculation of the CO_2 upptake of concrete for the given period in the countries participating in the project.

Further, as the report contains only data, conclusions are inappropriate in this report.

References

[1] http://www.ermco.org; January, 2004
[2] "Betonelementforeningens Årsberetning - Medlemsstatistik 1969", Dansk Betonelementforening, Kejsergade 2, 1002 København K, Denmark.
[3] "Betonelementforeningens Årsberetning - Produktionsstatistik 2003", Dansk Betonelementforening, Kejsergade 2, 1002 København K, Denmark
[4] "Dansk Beton Industriforening - Generalforsamling 2004, 1992, 1991", Dansk Beton Industriforening, Kejsergade 2, 1002 København K, Denmark.
[5] Based on statistics from the yearly assembly (2004, 1992, 1991) in "Dansk Beton Industriforening" (DBI)
[6] Based on statistics from the Norwegian Ready-Mixed Concrete Association (FABEKO)
[7] Based on production statistics from the Norwegian Precast Concrete Federation (Betongelementforeningen)