An LCA Study on a Concrete Structure by Variations of Compressive Strength of Concrete to define the characteristics of GHGs emission

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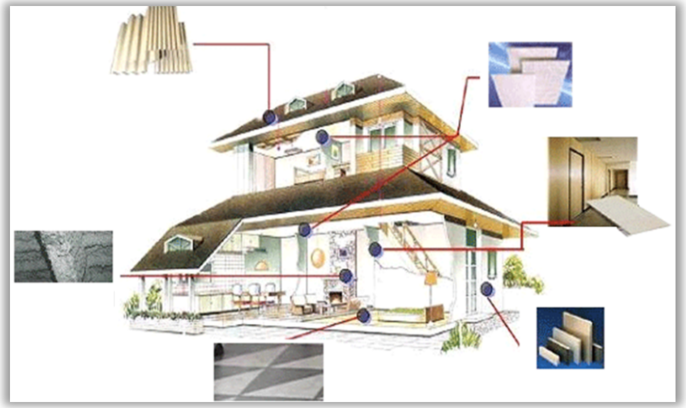
Contents

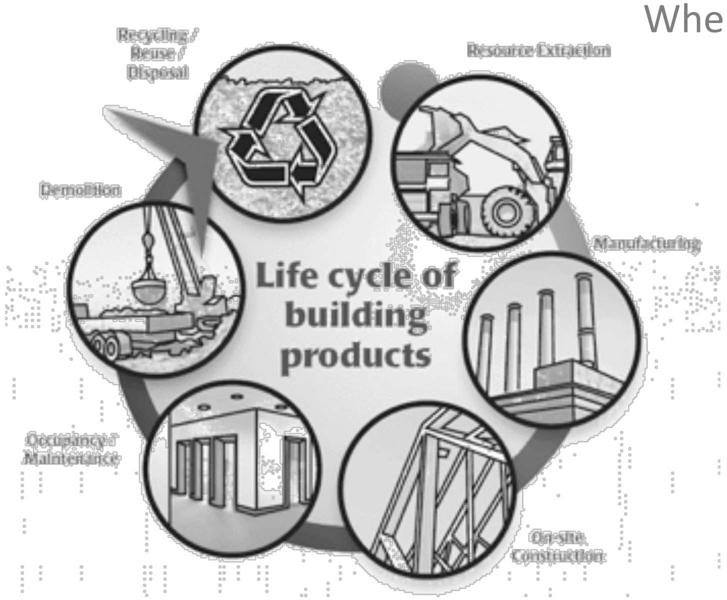
Introduction

Now	▪ All countries of the world, various carbon policies being implemented in order to mitigate of greenhouse gas emissions. ▪ Building sectors are required to participate in effort to reduce greenhouse gas emissions. ▪ This Study is intended to evaluate quantitatively potential impacts of concrete structure throughout its life cycle phases that has been an issues in relation to climate change, especially CO_2 emissions.
How	How to calculate the environmental burdens of buildings?  =∑(individual environmental impacts of building materials)

LCA Implementation

Overview | Definition of Life Cycle Assessment(LCA)

An LCA is a standardized method for examining a broad range of environmental impacts associat ed with a process or a product over its complete life cycle.
ISO 14044 is the accepted standard to use when performing an LCA.



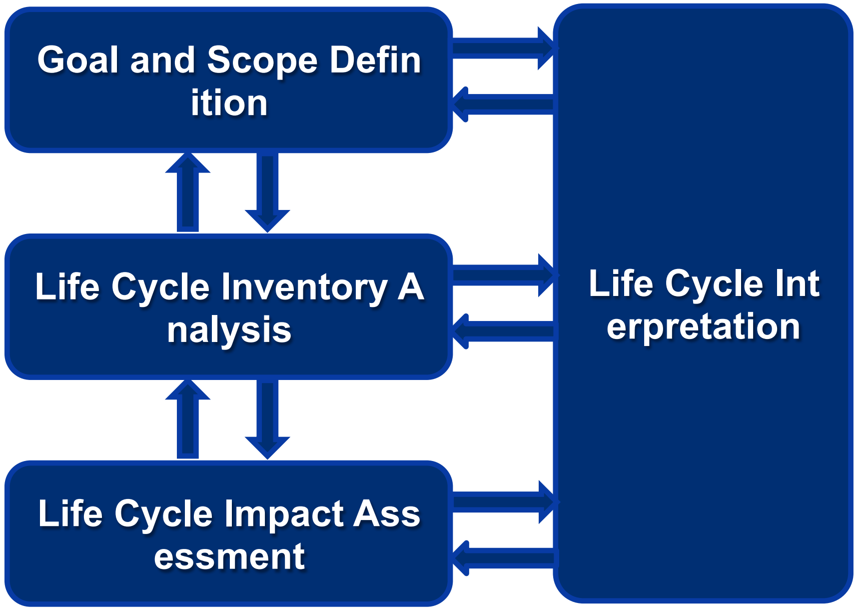
When applied to buildings, an LCA includes:

1) Raw materials extraction, Manufacturin g of materials(**Production**)
2) **Construction**
3) Building operations, including energy co nsumption and maintenance(**Use**)
4) **Disposal**/ reuse/ recycling

Figures Sources: http://www.pci.org/cms/index.cfm/sustainability/LCA

LCA Implementation

Overview | Components of Life Cycle Assessment(LCA)



1. **Setting goals and defining the scope**

   Selecting a goal is essential in helping to define the scope. Scoping i s important because defining the parameters of the study helps ens ure consistency of analysis and setting boundaries for the analysis c reates the basis for validation and comparisons.♪

2. **Life-cycle inventory (LCI)**

   The LCI step involves measuring and totaling the flows of inputs and outputs (i.e., fuel and materials use, air emissions, water use) of a s pecific product, process, system, or service in each stage of the life cycle. An LCI requires high-quality research, data collection, and dat a analysis.♪

3. **Life-cycle impact assessment (LCIA)**

   The LCIA uses the inventory to assess the impacts that the product, process, system, or service has made throughout its life cycle. A vari ety of methods and data sources can be used to determine these im pacts. Key impact categories include global warming and energy co nsumption. ♪

4. **Interpretation and communication♪**

   The interpretation is the synthesis and analysis of the inventory and the impact assessment. In this phase of an LCA, the goal and scope of the LCA are revisited and conclusions are made and communicat ed to illustrate how the product, process, or service is affecting the e nvironment and the business and what can be done to reduce its im pacts.♪

LCA Implementation

Overview | Procedure of LCA

Functions, Functional units and Reference flows

- Functional Unit
- The LCA process must be based on the same function and functional unit.
- Reference flow

System Boundary

- System Boundary
- Production, manufacturing
- Inputting building Materials
- Using the building

Data Collection

- Activity Data
- Field data
- Transportation on data
- Disposal and recycling scenario

Data Calculation

- Calculation Method:

CO_2 emissions
= Activity Data
X
GHG emissions Unit

LCA Implementation

Overview — Comparative Assessment Plan

Assumptions and Limitations

- A variety of concrete mixes are chosen with different use of cement. The amount of material inputs v aries in each mix and the resulting durability and environmental burdens also can be different.
- In this study, the use and duration of concrete products remain the same, and by assessing them only with g eneral and high compressive strength are analyzed.
- The assessment was carried out by varying the compressive strength of concrete from 24MPa, 40MPa, 60MP a.♪

Compressive Strength	• 25MPa, 40MPa, 60MPa
Assessment Period	• 120 years (but, in case of 24Mpa, assessment period is 60 years.)
Applied area	• The walls of reinforced concrete wall structure

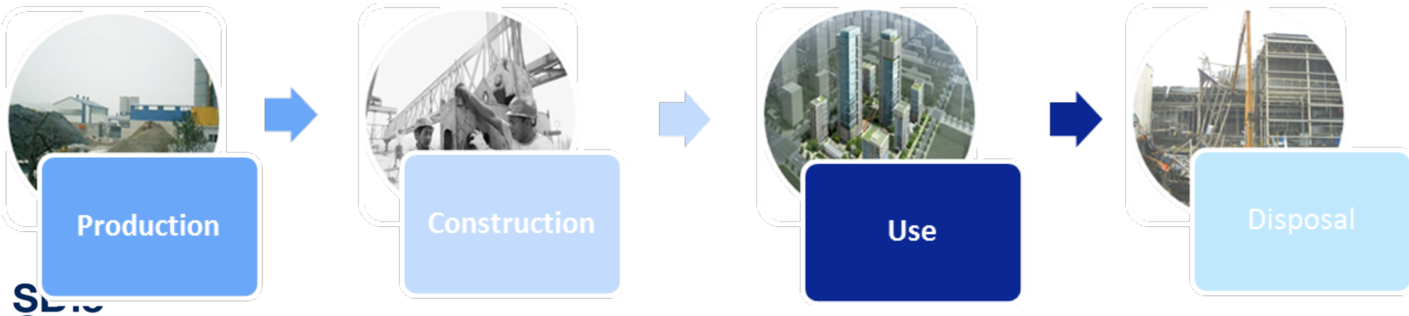
LCA Implementation

Overview — Requirements for assessment

Function, Functional Unit and Reference Flow

Function	• To form structural wall of reinforced concrete apartment building
Functional Unit	• Reinforced concrete wall of 25-story apartment building occupied during 120 years
Reference Flow	• Materials and energy which put into reinforced concrete wall of 25-story apartment building occupied during 120 years

System Boundary for LCA Concrete Building



LCA Implementation

Overview | Requirements for assessment

Scope of Data Collection

- The follow table is referred to an **actual mixture ratio table** from ready-mixed concrete company.
- The table shows that data on major constituent materials based on “Cut-off criteria(95%~99%)”.♪

Strength	Materials (kg/m^3)					
	Aggregate	Sand	Portland Cement Type I	Water	Admixture	Total
24MPa (25-24-150)	931 **(40%)**	863 **(38%)**	334 **(15%)**	170 **(7%)**	2.34 **(0%)**	2300.34 (100%)
40MPa (25-40-150)	896 **(39%)**	748 **(33%)**	459 **(20%)**	163 **(7%)**	6.63 **(0%)**	2272.63 (100%)
60MPa (20-60-600)	905 **(41%)**	705 **(32%)**	426 **(19%)**	165 **(7%)**	6.09 **(0%)**	2207.09 (100%)

LCA Implementation

Overview — Requirements for assessment

Life cycle assessment scenarios

Stage	Phase	Data Collection	GHG Emission Unit	Supposition
Production	**Material Manufacturing**	**Aggregate** **Sand** **Portland Cement Type I** **Water**	6.65E-03 $kgCO_2e/kg$ (KLCI) 2.42E-03 $kgCO_2e/kg$ (KLCI) 9.48E-01 $kgCO_2e/kg$ (KLCI) 1.14E-04 $kgCO_2e/kg$ (KLCI)	Materials within 95% of the cumulative weight contribution
	Transportation	Energy consumption	KLCI, Carbon Labeling, IPCC	Transport data between manufactories
Construction	**Construction/ Installation**	**Oil consumption By Concrete Pump Car**	2.66E+00 kgCO2e/L (Carbon Labeling)	Activity data related with construction machinery
	Transportation	Energy consumption	KLCI, Carbon Labeling, IPCC	Transport data between manufactories and site
Use	**Maintenance**	**Aggregate, Sand, Portland Cement, Water** consumption	KLCI, Carbon Labeling, IPCC	Activity data related with product maintenance
	Transportation	Energy consumption	KLCI, Carbon Labeling, IPCC	Transport data between product manufactories and building
Disposal	Deconstruction	Energy consumption	KLCI, Carbon Labeling, IPCC	Activity data related with machinery
	Transportation	Energy consumption	KLCI, Carbon Labeling, IPCC	Transport data disposal facility
	Disposal	**Waste Concrete Reclamation**	7.00E-03 $kgCO_2e/kg$ (Carbon Labeling)	Activity data related with waste landfill
	Recycle	**Waste Concrete Recycling**	1.99E-01 $kgCO_2e/kg$ (Carbon Labeling)	Activity data related with recycling

Case Study: Comparison of CO_2 Emission

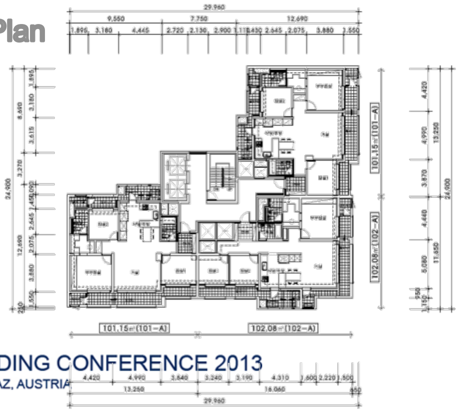
Case Calculation of the amount of Concrete

➢ Building Summary♪

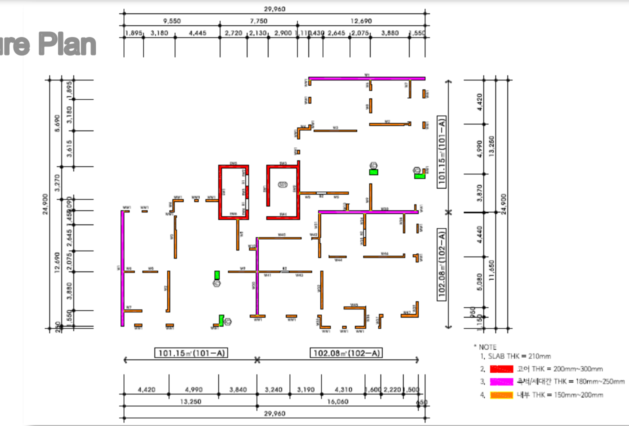
- Structure type : Reinforced concrete structural wall system
- Building size : 3 stories below and 25 above the ground(305㎡/level)

Strength	Wall Thickness			Concrete Quantity
	Core	External wall	Inside wall	
24MPa (25-24-150)	300mm	250mm	200mm	3,032.2m³
40MPa (25-40-150)	250mm	200mm	180mm	2,490.0m³
60MPa (20-60-600)	200mm	180mm	150mm	2,100.7m³

Architectural Plan



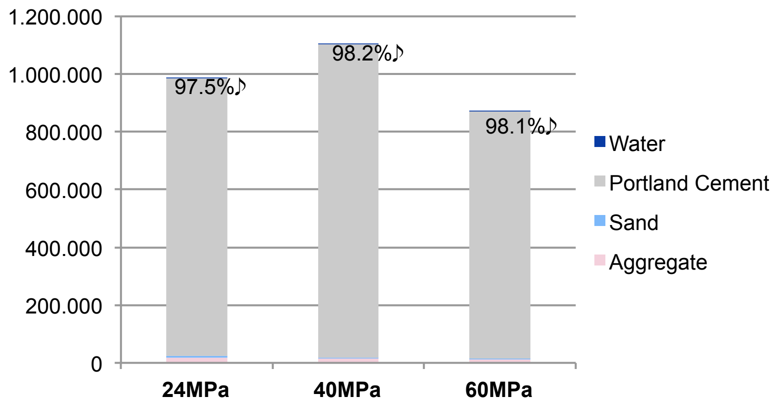
Structure Plan



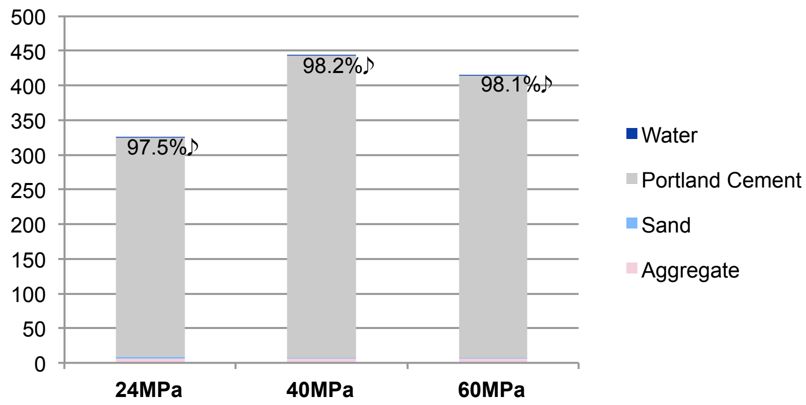
Case Study: Comparison of CO_2 Emission

CO_2 Emission | Production stage

- Total volume of CO_2 Emission by strength



- CO_2 Emission per m³ by strength



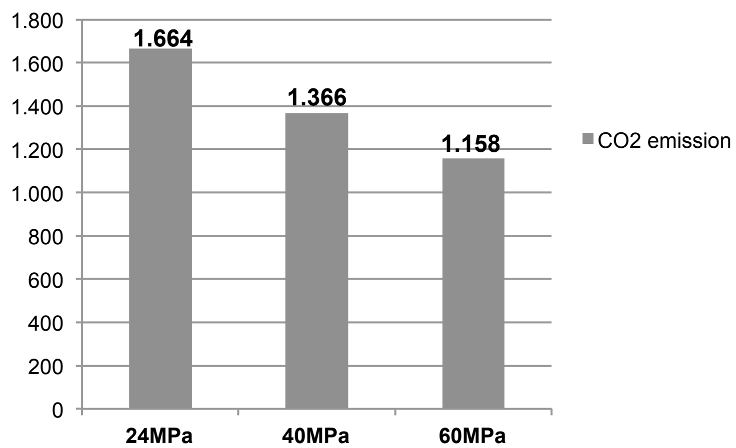
Strength	Concrete Quantity	CO_2 emission ($kgCO_2eq$)				
		Aggregate	Sand	Portland Cement Type I	Water	Total volume
24MPa (25-24-150)	3,032.2m³	18,765 (1.90%)	6,329 (0.64%)	960,092 (97.45%)	59 (0.01%)	985,244 (324.93 $kgCO_2eq/m^3$)
40MPa (25-40-150)	2,490.0m³	14,830 (1.34%)	4,505 (0.41%)	1,083,479 (98.24%)	46 (0.00%)	1,102,860 (442.92 $kgCO_2eq/m^3$)
60MPa (20-60-600)	2,100.7m³	12,697 (1.46%)	3,599 (0.41%)	852,402 (98.12%)	40 (0.00%)	868,738 (411.59 $kgCO_2eq/m^3$)

※ Materials unit : kg/m³

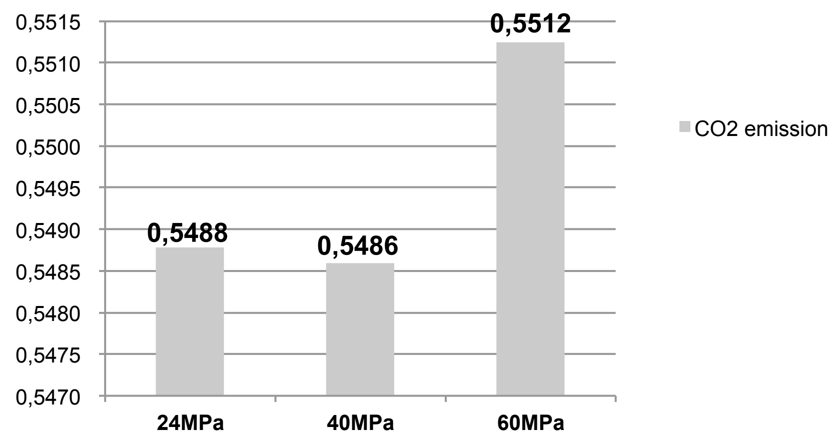
Case Study:
Comparison of CO_2 Emission

CO_2 Emission | Construction stage

- **Total volume of CO_2 Emission by strength**



- **CO_2 Emission per m^3 by strength**

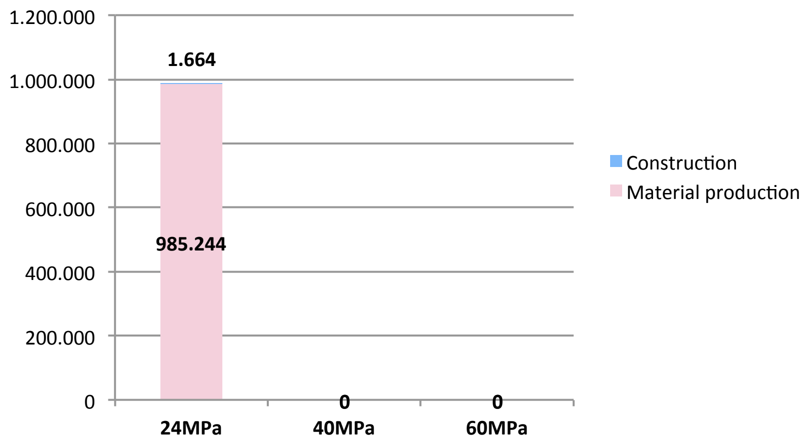


Strength	Concrete Quantity	Pump Car Capacity	Pump Car Working	Pump Car Diesel Consumption	GHG Emission Unit of Diesel	CO_2 emission($kgCO_2eq$)
24MPa (25-24-150)	3,032.2m^3	80m/hr Diesel Consumption 16.5L/hr	37.9 hr	625.39 L	2.66E+00 $kgCO_2$-eq/L	1,664 (0.5488 $kgCO_2eq/m^3$)
40MPa (25-40-150)	2,490.0m^3		31.13 hr	513.56 L		1,366 (0.5486 $kgCO_2eq/m^3$)
60MPa (20-60-600)	2,100.7m^3		26.38 hr	435.33 L		1,158 (0.5512 $kgCO_2eq/m^3$)

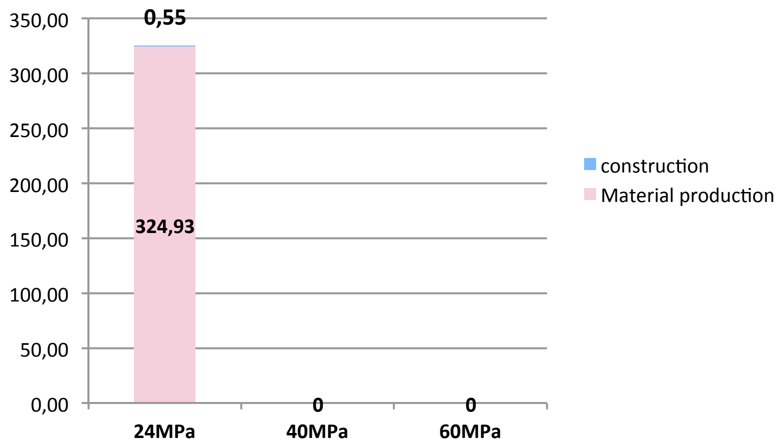
Case Study:
Comparison of CO_2 Emission

CO_2 Emission | Use stage

- **Total volume of CO_2 Emission by strength**



- **CO_2 Emission per m³ by strength**

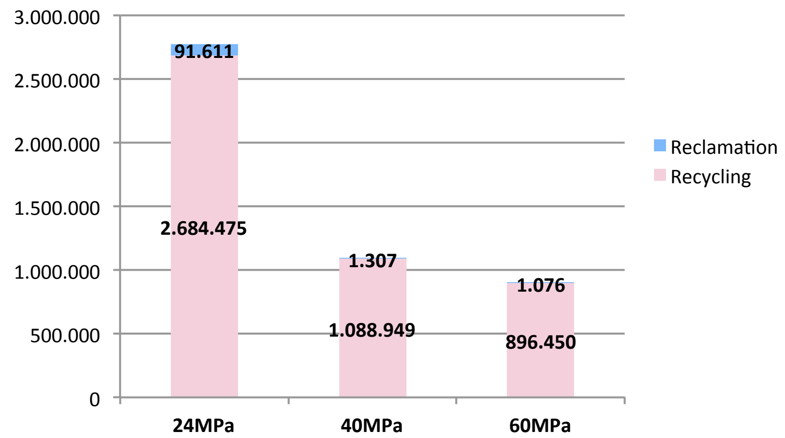


Strength	Concrete Quantity	Assessment period	Rebuilding	CO_2 emission ($kgCO_2eq$)		
				Materials production	Construction	Total
24MPa (25-24-150)	3,032.2m³	120 year	1	985,244	1,664	986,908 (325.48 $kgCO_2eq/m^3$)
40MPa (25-40-150)	0		N/A	0	0	0
60MPa (20-60-600)	0		N/A	0	0	0

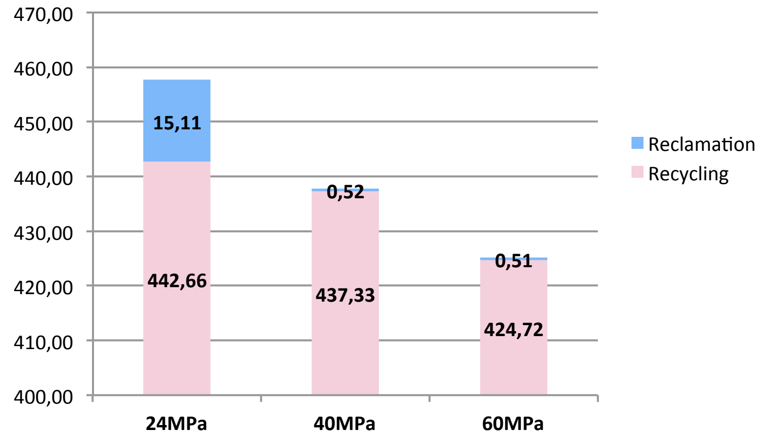
Case Study: Comparison of CO_2 Emission

CO_2 Emission Disposal stage

➢ **Total volume of CO_2 Emission by strength**



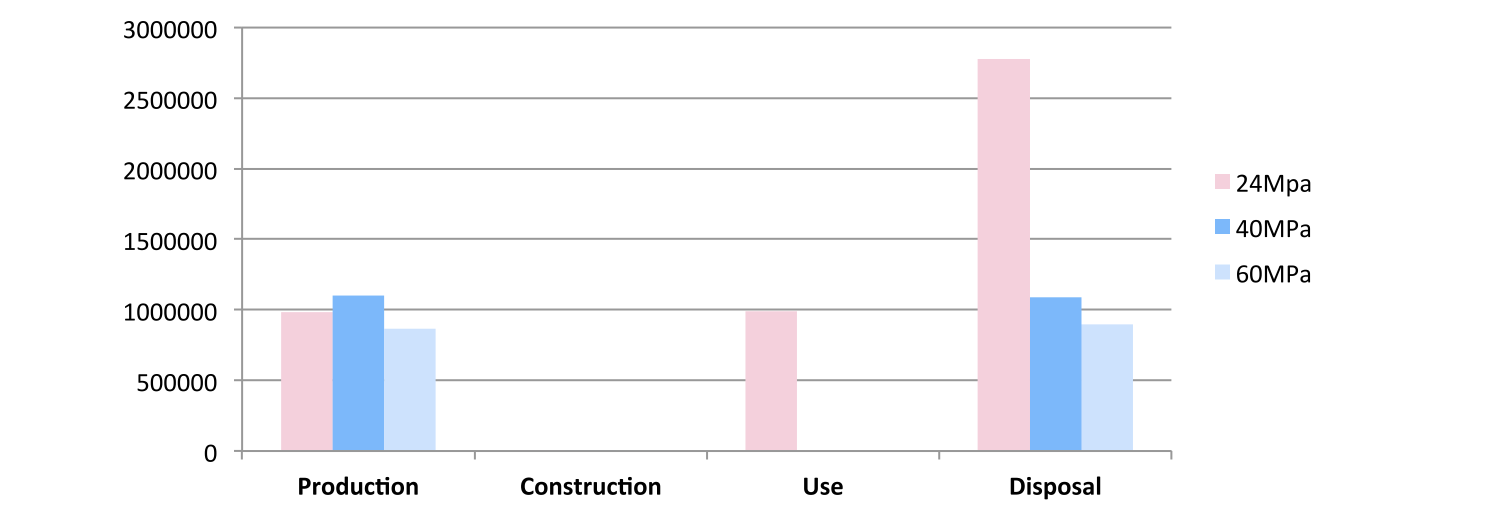
➢ **CO_2 Emission per m³ by strength**



Strength	Concrete Quantity	Assessment period	Waste Treatment	Waste Concrete (ton)		GHG emission (kgCO2-eq./kg)	CO_2 emission ($kgCO_2eq$)		
				Recycling	Reclamation		Recycling	Reclamation	Total
24MPa (25-24-150)	6,064.4m³	120 year	▪ Recycling (96.7%) ▪ Reclamation (3.3%)	13,490	460	▪ Recycling (1.99E-01) ▪ Reclamation (7.00E-03)	2,684,475	91,611	2,776,086 (457.77 $kgCO_2eq/m^3$)
40MPa (25-40-150)	2,490.0m³			5,472	187		1,088,949	1,307	1,090,256 (437.85 $kgCO_2eq/m^3$)
60MPa									897,526

Case Study:
Comparison of CO_2 Emission

CO_2 Emission | Results of the LCA



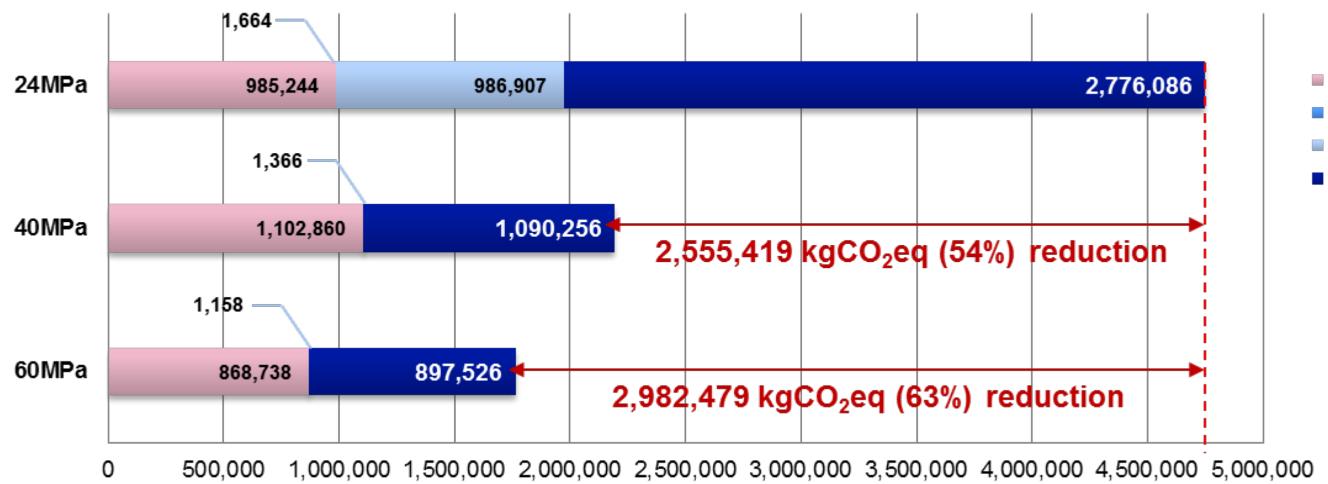
Strength	Concrete Quantity	Assessment period	CO_2 emission ($kgCO_2eq$)				
			Production	Construction	Use	Disposal	Total
24MPa (25-24-150)	6,064.4m^3	120 year	985,244 (162.46 $kgCO_2eq/m^3$)	1,664 (0.27 $kgCO_2eq/m^3$)	986,907 (162.74 $kgCO_2eq/m^3$)	2,776,086 (457.77 $kgCO_2eq/m^3$)	4,749,901 (783.24 $kgCO_2eq/m^3$)
40MPa (25-40-150)	2,490.0m^3		1,102,860 (442.92 $kgCO_2eq/m^3$)	1,366 (0.55 $kgCO_2eq/m^3$)	0	1,090,256 (437.85 $kgCO_2eq/m^3$)	2,194,482 (881.32 $kgCO_2eq/m^3$)
60MPa (20-60-600)	2,100.7m^3		868,738 (413.55 $kgCO_2eq/m^3$)	1,158 (0.55 $kgCO_2eq/m^3$)	0	897,526 (427.25 $kgCO_2eq/m^3$)	1,767,422 (837.36 $kgCO_2eq/m^3$)

Conclusions and Further Studies

Conclusion Analyzing the Global Warming effects by Assessment Period

Assessment Period:

120yrs

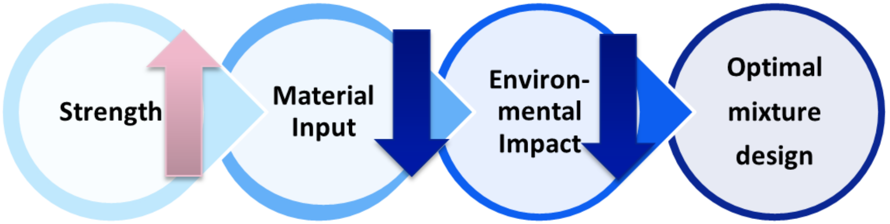


- Due to the difference of durability by compressive strength,
  - about 54% of CO_2 emissions reduction was shown in case of 40MPa,
  - about 63% of CO_2 emissions reduction appeared in the 60MPa,
  - in comparison with 24MPa over the life cycle of 120 years.

Conclusions and Further Studies

Conclusion Main Factors for Reducing the Environmental Impact

Production Stage	• Quantity of Cement Inputs
Construction Stage	• Quantity of Concrete
Use Stage	• Durability(service life) of Concrete Structure
Disposal Stage	• Quantity of waste concrete



➢ Based on these results, further studies are needed to:

- perform the various matrix cases with more accurate calculation and hypothesis
- and present optimal design of concrete structure considering the durability and environment impact.

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Thank you for your attention!

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