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# LIFE-CYCLE INVENTORY ANALYSIS PROGRAM FOR ROAD CONSTRUCTION

-development and experiences of use

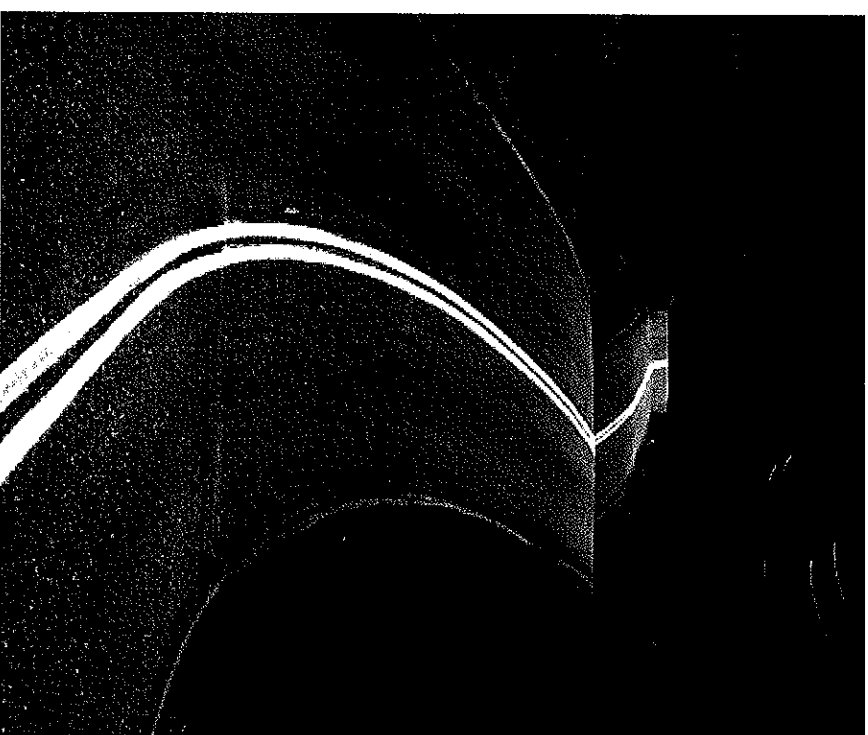
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# LIFE-CYCLE INVENTORY ANALYSIS PROGRAM FOR ROAD CONSTRUCTION

1. Scope
2. System boundaries
3. The LCA-program
4. Case studies
5. Conclusions



## SCOPE

- Clear and functional LCA-methodology for road constructions
- Extensive database taking account of the special features of road constructions
- Inventory analysis program for calculation and comparison of environmental loadings of the most common road constructions
- Inclusion of industrial by-products (fly ash, crushed concrete waste, blast furnace slag)
- Simple and easy to use
- Applicability as part of routine road planning and decision-making

## SYSTEM BOUNDARIES

- Constructions are examined as entities
- Calculations are made for a chosen functional unit
- Period of use 50 years
- Calculations enable comparisons between individual structural components and work stages
- Primarily local or material-specific data is used
- Pavement and sub-grades are treated as separate entities, all though combination is also possible

# SYSTEM BOUNDARIES: Materials

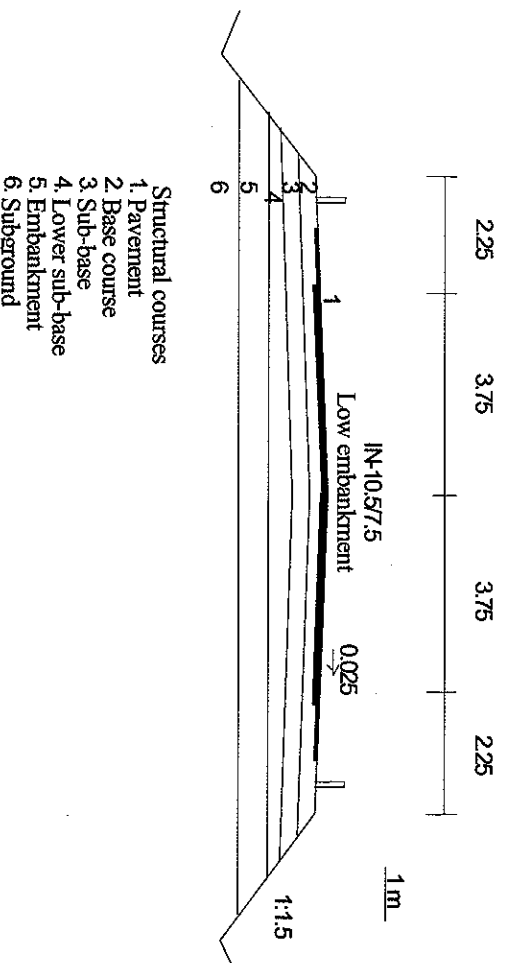
Pavements: different asphalt types

Base: crushed aggregate, crushed concrete waste, crushed BF-slag, bitumen gravel, soil cement (cement stabilisation)

Sub-base: crushed aggregate, gravel, fly ash, fly ash+cement, crushed concrete waste, BF-sand, crushed BF-slag, lightweight aggregate

Filter layer: sand, BF-sand, lightweight aggregate

Embankment fill: sand, crushed rock, lightweight aggregate



## SYSTEM BOUNDARIES: Functions

### FUNCTIONS

#### INCLUDED

All significant life-cycle stages:

- Material production (By-products: storage area)
- Transportation of materials
- Road construction
- The use of road (pavement reconstruction, leaching)
- (Landfill disposal / by-products)

#### NOT INCLUDED

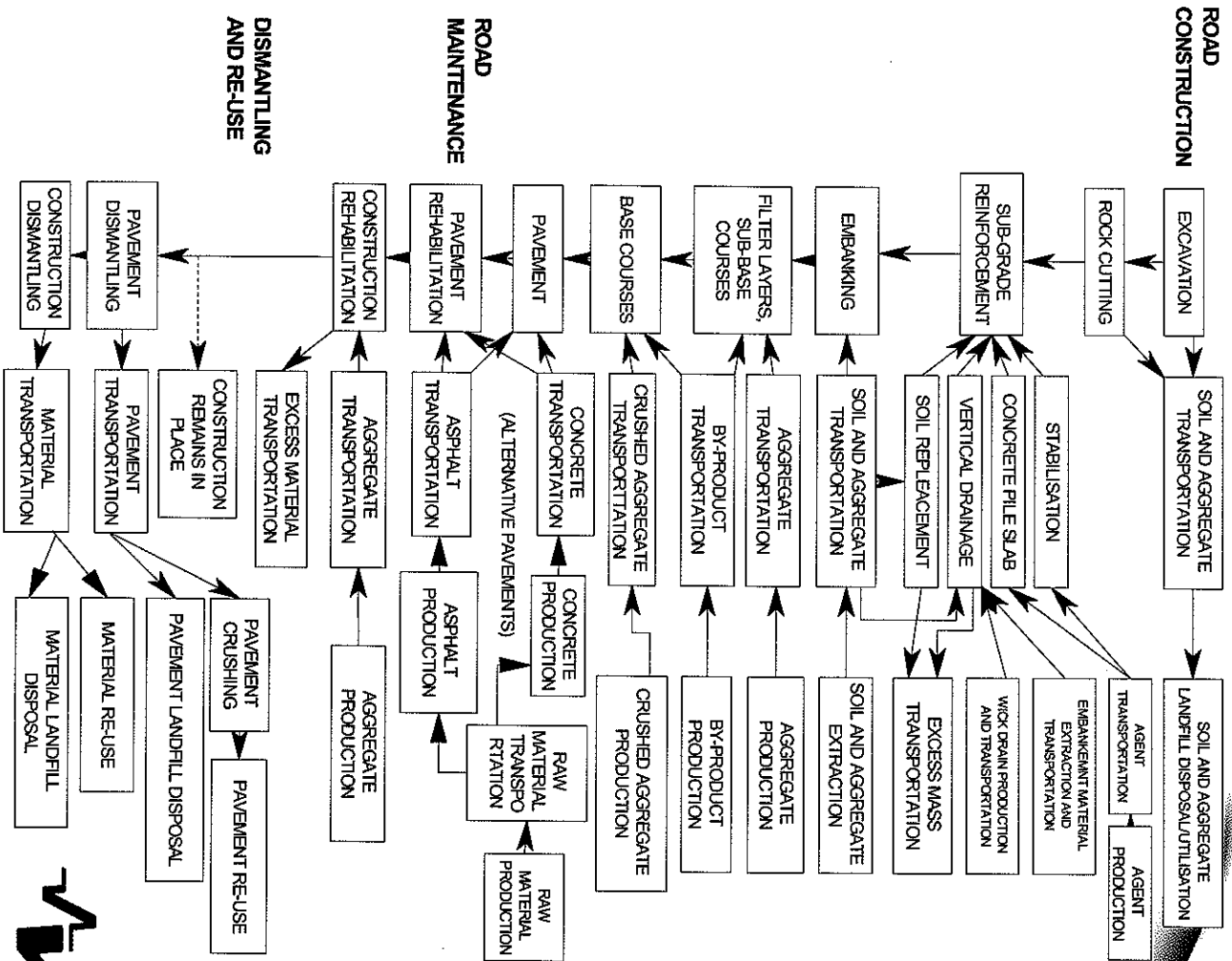
Stages with no effect on comparisons:

- Site clearance
  - Functions associated with road use (lane markings, traffic signs, lights)
  - Regular or seasonal maintenance (snowploughing, salting, sanding)
  - Traffic emissions
- Situation after use

# PRINCIPAL ROAD CONSTRUCTION AND USAGE PHASES

## Material production chains

	<b>Starting point:</b>
Natural aggregates	Bedrock excavation or excavation from ground
Cement and lime	Extraction of raw materials
Rubber	Production of crude oil
Industrial by-products	Stockpile (by-product production processes not included)



# SYSTEM BOUNDARIES: Environmental loadings

## 1. Use of resources

- Natural raw materials
- Industrial by-products
- Energy and fuel consumption

## 2. Atmospheric emissions

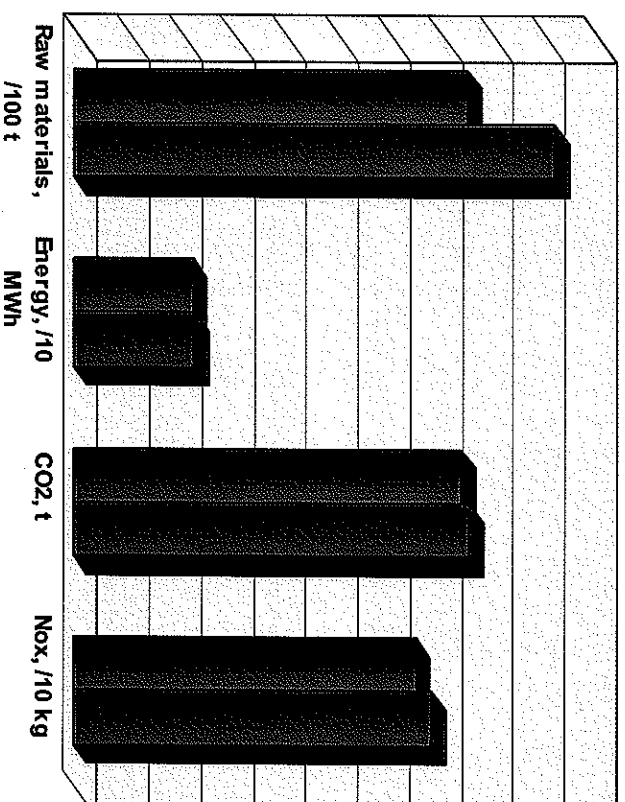
- Carbon dioxide and monoxide
- Nitrogen oxides
- Sulphur dioxide
- Volatile organic compounds
- Particles

## 3. Leaching into the ground

- Heavy metals, chloride, sulphate

## 4. Other loadings

- Noise, dust, transportation distance

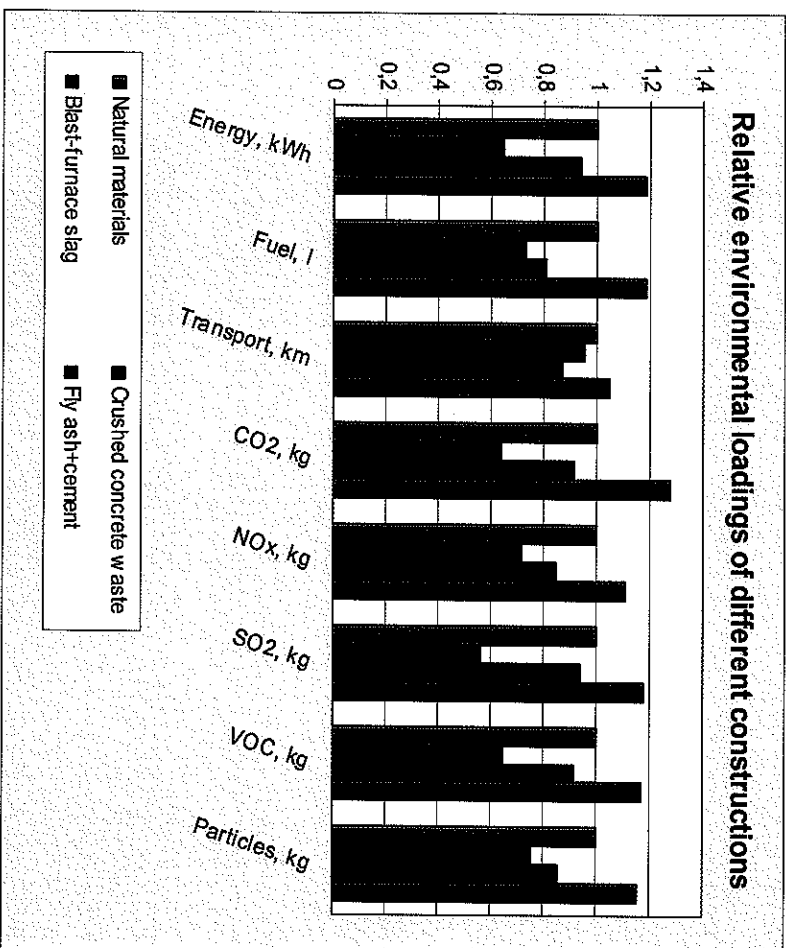




# ENVIRONMENTAL IMPACT ASSESSMENT

## EFFECT SCORING

- made on basis of expert assessment
- loadings were converted into relative values using the reference construction as base level
- impact categories were proportioned to one another using the comparative scores obtained from the expert assessment



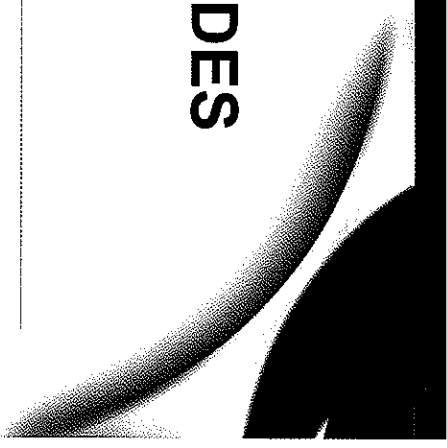
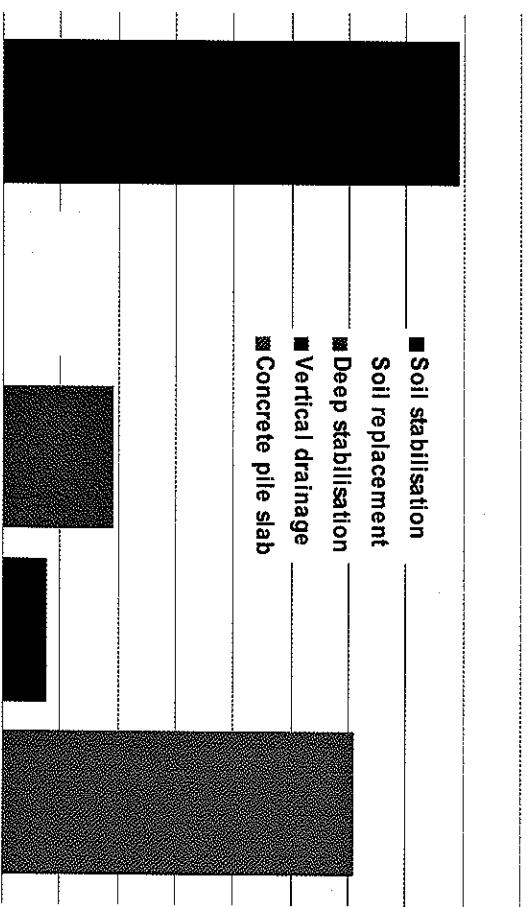
## INVENTORY ANALYSIS PROGRAM

- Suitable for routine calculations of environmental loadings of different road constructions, both common pavement structures and sub-grades
- Input data:
  - dimensions of the construction
  - materials and thicknesses of the structural courses
  - transport distances of materials
- A number of standard graphical presentations are already included
- Presentation of environmental loadings for selected materials and courses by principal work stage or as total loading
- Rapid comparisons of pavement structures are possible
  - comparisons possible as such, in relation to fixed reference or as effect scores

# ENVIRONMENTAL LOADINGS OF SUB-GRADES

## CONSTRUCTION TYPES

- Soil stabilisation
- Soil replacement
- Deep stabilisation
- Vertical drainage + drainage course
- Concrete pile slab



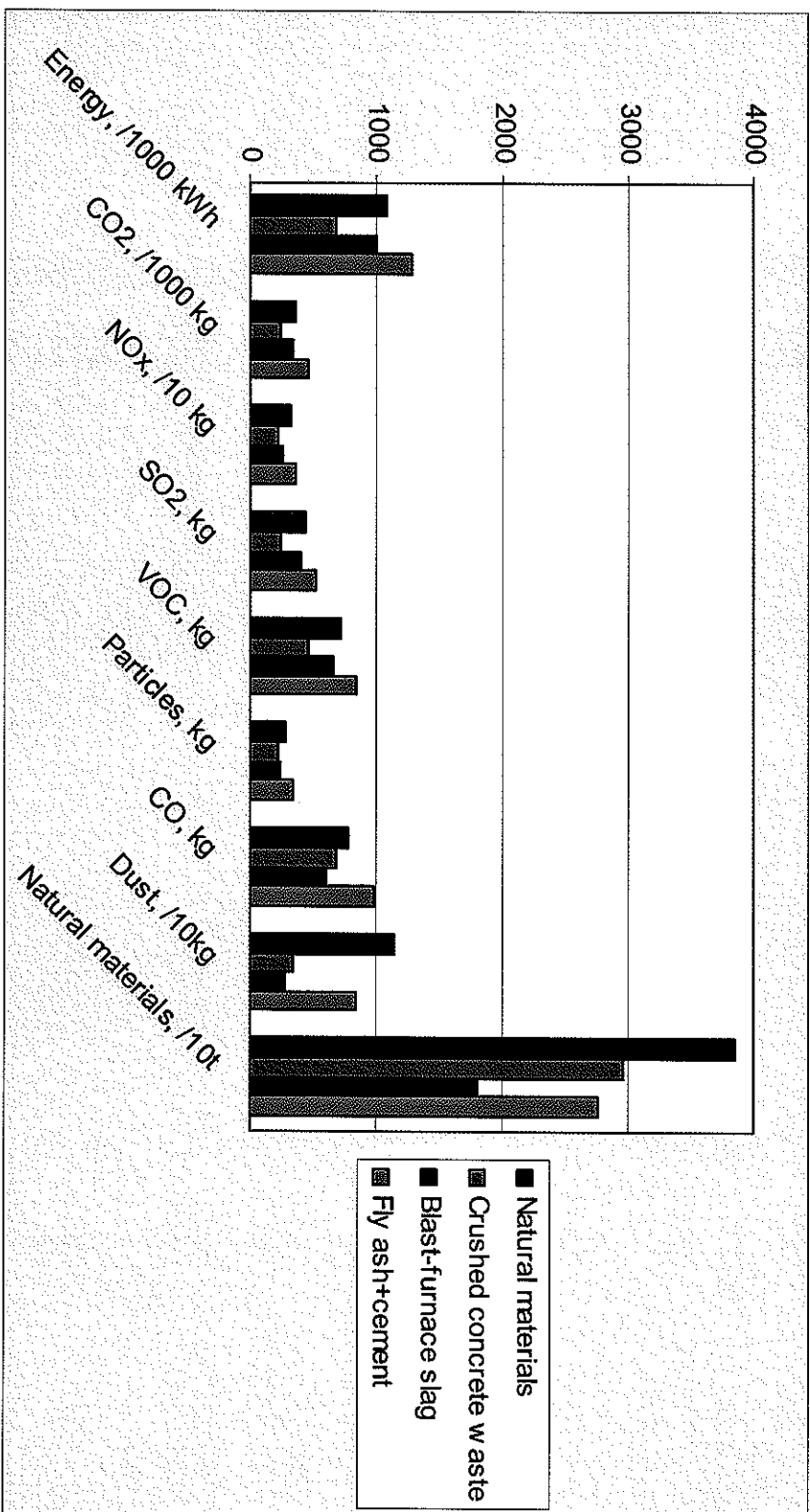
## RECENT DEVELOPMENTS IN THE PROGRAM

- Background data checked and updated
- New materials added: lightweight aggregate, steel slag and soil cement
- Environmental loadings of cement updated
- Negotiations with other material producers
- A standard print-out with main results
- Testing of the program in actual road planning cases

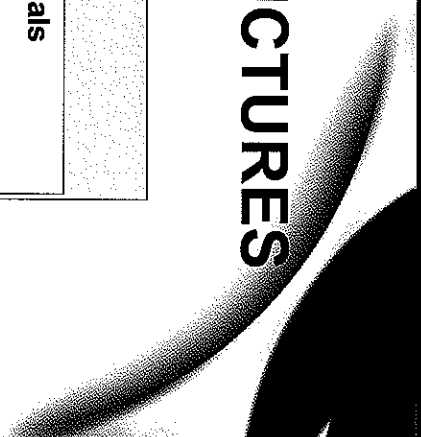
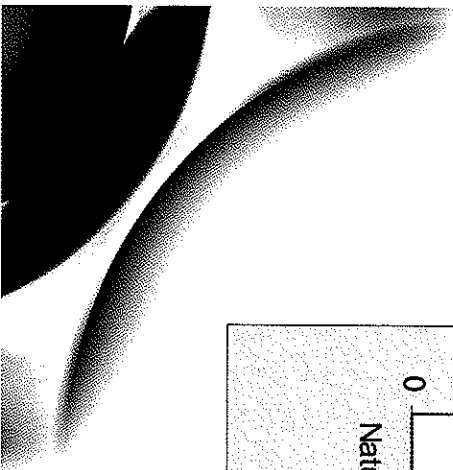
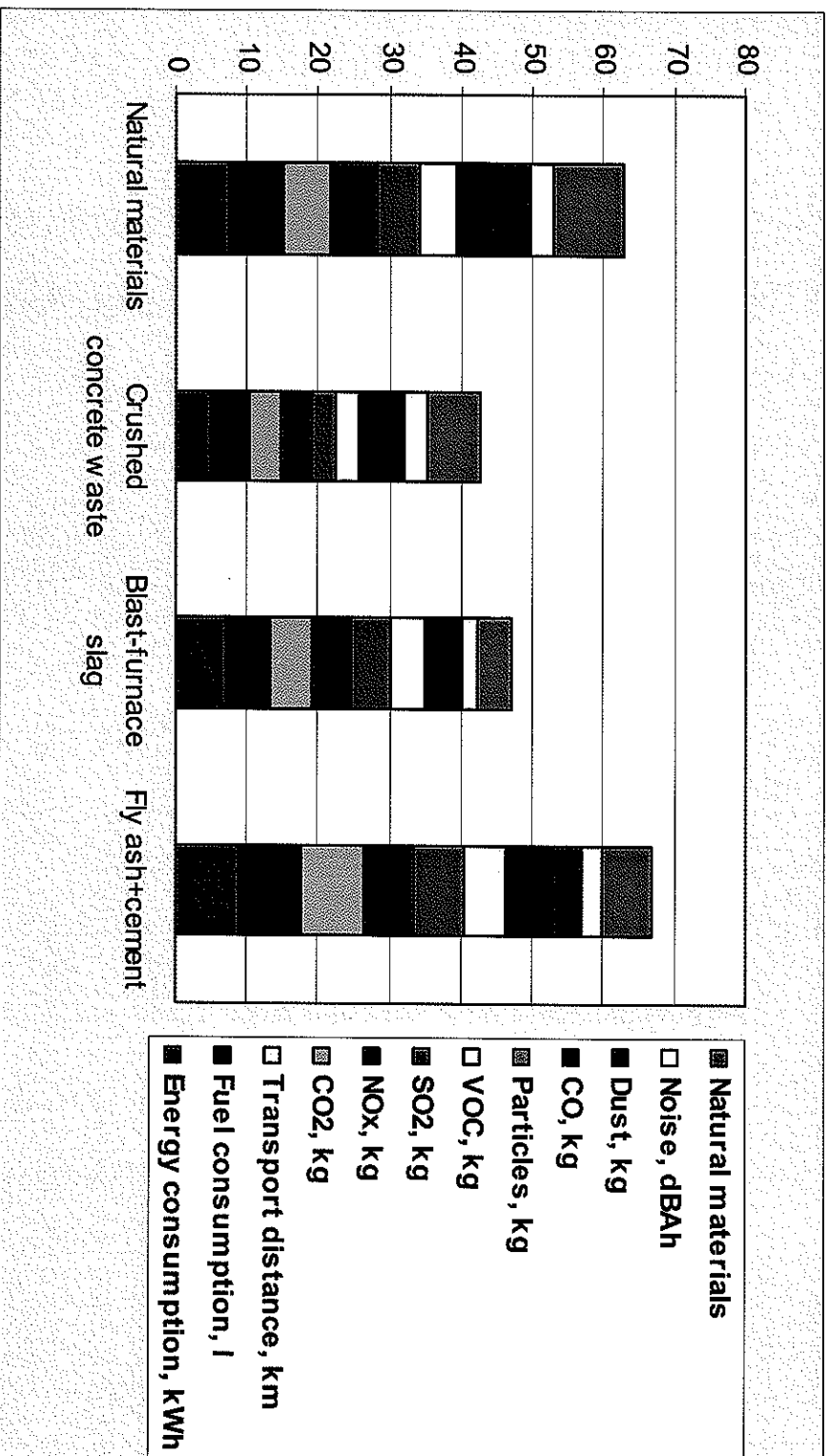
## CASE STUDIES

Structural layer	Natural aggregate	Crushed concrete waste	Blast-furnace slag	Fly ash+cement
Pavement	160 mm AB 20/120	80 mm AB 20/120	160 mm AB 20/120	160 mm AB 20/120
Base course	250 mm Crushed stone 0-35	200 mm Crushed concrete 0-50	100 mm Crushed blast-furnace slag	150 mm Crushed stone 0-35
Sub-base	250 mm Gravel	200 mm Crushed concrete	250 mm Granulated blast-furnace slag	350 mm Fly ash+cement 2%
Lower sub-base	250 mm Sand	450 mm Sand	200 mm Granulated blast-furnace slag	200 mm Sand
Total thickness	910	930	710	860
Embedment	500 mm Sand	500 mm Sand	500 mm Sand	500 mm Sand

# ENVIRONMENTAL LOADINGS OF PAVEMENT STRUCTURES

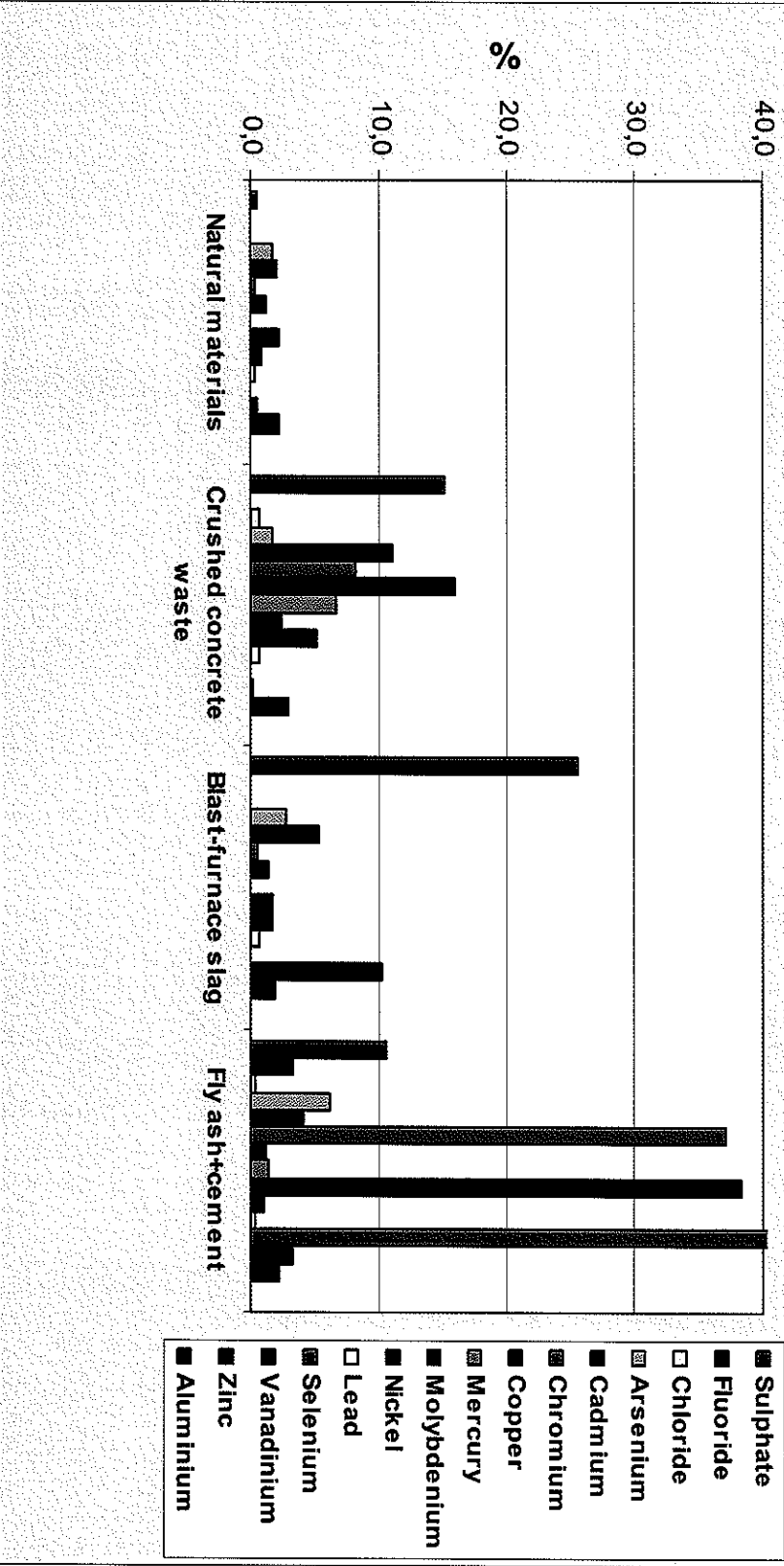


# WEIGHTED COMPARISON OF PAVEMENT STRUCTURES



# LEACHING

Substances leaching out of constructions compared with Dutch immission values (100 years)





## CONCLUSIONS

- Simple and easy to use
- Suitable for routine calculations of environmental loadings
- Comparison of alternative constructions and presentation of results is easy
- Wider use would require adding more materials and working methods
- Advances the environmental consciousness of designers and contractors
- Motivates the development work of materials and construction equipment