**CEDR – Transnational Programme 2012: Recycling**

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# Environmental Impact in Terms of Carbon Footprint and Eco-balance Cold Recycling Pavement Technology

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# Tools for carbon footprint assessment and for LCA today

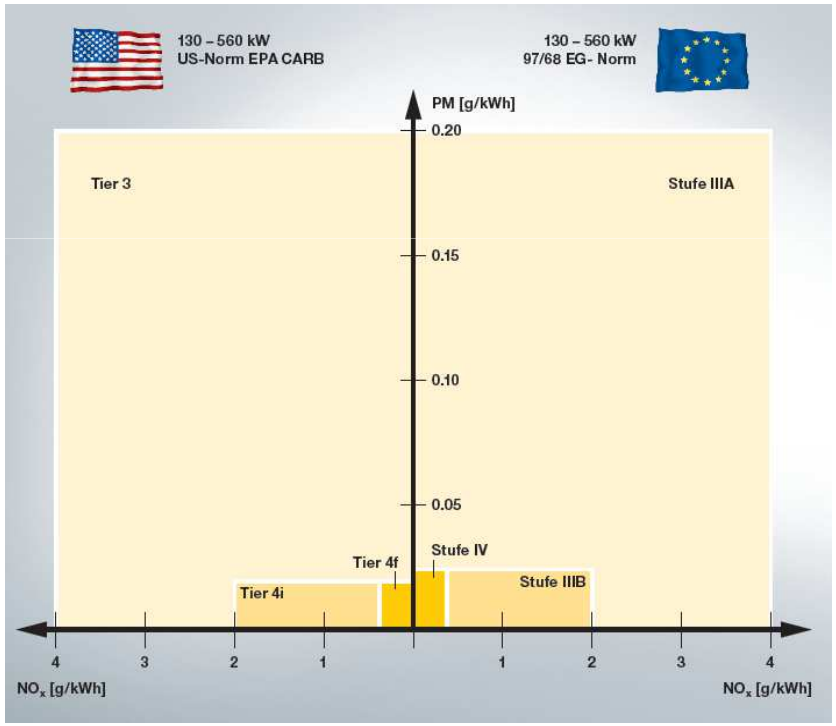
## Original intention within CoRePaSol

- Identification of some suitable tools which exists in Europe, modify, imply and complement them with respect to cold recycling technologies;
- Analysis of pavement cold recycling techniques with respect to calculation of emission content ($CO_2$, NOx, HC, CO and particle matters);
- Originally project CEREAL was understood as a suitable candidate (tool Carbon RoadMap);
- Later discussions about UK´s asPECT;
- Condition was to incorporate detailed data of construction machines (comparison of various classes of EPA/TIER).


# Tools for carbon footprint assessment and for LCA today

## Specifics of carbon footprint of machinery used

- European Union and other countries in the world did major progress in limitation of emissions of construction machineries. Beside the emissions of $CO_2$ there had been introduced major limitations to carbon monoxide CO, NOx, HC and fine particle matters in the last years. This legislation is known as TIER4 interim (final) /EPA IV interim (final) standard. It is forced by the directive 97/68/EC.



# Actual situation in the area of carbon footprint and LCA tools

## Existing software applications

- Cooperation and use of CEREAL project solution failed;
- Extensive review with the target to summarize pros and cons of some existing calculators used in the field carbon footprint assessment in road engineering within Europe;
- Review supplemented by experience and knowledge from experts (real practice);
- In total 17 tools (software) were described, whereas nine were subjected to detail analysis.

*(RoadMap CEREAL; asPECT; Afwegingsmodel wegen; AggRegain CO2e; ROAD-RES; DuboCalc; JouleSave; GreenDOT; PaLATE; WLCO2T; SEVE; CHANGER; Ecologiciel (Colas); CO2NSTRUCT; LCI Model; HDM-4; VETO).*

# Actual situation in the area of carbon footprint and LCA tools

| Software name | Advantages (+) | Disadvantages (-) |
|---|---|---|
| RoadMap CEREAL | + accessibility of the database<br>+ open architecture | - not yet available due to technical problems<br>- did not calculate deeply with recycling techniques |
| asPECT (UK) | + accessibility of the database | - needs large amount of data |
| AfwegingsModel Wegen (NL) | + transparent and simple<br>+ includes maintenance the possibility to use updated data | - impossible to add data into existing database |
| AggRegain / ESRSA (UK) | + accessibility of the database | - needs large amount of input detailed data |
| ROAD-RES (DK) | + good methodological structure | - needs large amount of input detailed data |
| DuboCalc (NL) | + complexity of the database | - non-transparent process of results calculation |
| JouleSave (EU) | + includes the effect of interaction between the roadway and traffic load | - needs detailed knowledge of roadway design parameters |
| GreenDOT (US) | + good design and ergonometrics | - applicable in the US |
| PaLATE (US) | + good design/structure and ergonometrics | - applicable in the US |
| WLCO2T (UK) | + useful database based on Price Book (UK) | |

# Actual situation in the area of carbon footprint and LCA tools

## What have we learnt from existing apps?

- Usually closed (i.e. non-transparent with respect to used calculation principles and the possibility to add new data);
- Require big data contents and are often complex;
- Usually concentrate on new structures and do not take into account maintenance and rehabilitation on the whole range;
- European models have in general problem to present brief and explicit result, US models are in this respect more accommodating;;
- European carbon footprint models contain high scores of useful data, which we are so far not able to fully exploit;
- Particular apps are specific with respect to their origin. E.g. DuboCalc contains detailed information about the situation in Denmark, asPECT and ROAD RES contains detailed information from the UK and Scandinavia, etc.

# OptiRec – alternative software application – some facts

- Traditional calculation of the carbon footprint and greenhouse gas emissions and quantification of the impacts on the total life cycle costs.
- Tool uses stochastic methods for calculations of total $CO_2$ emissions and other air pollutants.
- Selection of appropriate recycling technology.
- Wide machine database:
  - own made & modified (close cooperation with one of the key machinery producers)
  - recyclers, compactors, rollers, graders, trucks, tankers
- User guide.
- Machine & Material catalogue.
- Practical examples (case study).
- Excel-based software application (current status).
- Further development and update expected .

# OptiRec/OptiRoad – covered topics

## Current

- Cement based cold recycling (cement slurry)
- Pulverization
- Cold recycling – bituminous emulsion
- Cold recycling – foamed bitumen
- Cold recycling – bitumen and hydraulic binder combination
- Cold milling with new paving of asphalt layers
- Pavement overlay
- Hot recycling (in progress now)

## Future

- Soil stabilization
- Further extension based on users request

## Future app extensions

- On-line app
- Shared database
- Sample project in database
- Graphs and statistics
- Language mutations
- Time planning

# OptiRec – Basic specification of project

OptiRec

## BASIC SPECIFICATION OF THE ROAD:

| | |
|---|---|
| Road location: | Europe |
| Country: | Czech Republic |
| Road classification: | Expressway |
| Pavement structure type: | Asphalt pavement |
| Length [m]: | 1200,00 |
| Width avg. [m]: | 4,75 |
| Thickness of reconst. layers) [mm]: | 150 |
| Thickness of new wearing course [mm]: | 50 |
| Distance to mixing plant/center [km]: | 50 |
| Carriers emisson category: | Euro 5 |

## DETAIL SPECIFICATION OF MACHINE SET:

| | |
|---|---|
| Operator gross salary [€/hr] | 12,00 |
| Worker gross salary [€/hr] | 10,00 |
| Diesel fuel price [€/l] | 1,28 |
| Key machine occupancy (recycler) [%] | 75 |
| Staff occupancy [%] | 100 |
| Annual use of key machine [hrs]: | 1 334 |

# OptiRec – Technical specification and material inputs

## REHABILITATION CHARACTER

| | |
|---|---|
| Way of Rehabilitation | Cold Recycling - foamed bitumen |
| Stabilisers (pre spreaded or mixed-in) | Cement (pre-spreaded) |
| Overall Character of Machines in use* | Eco-friendly |

## ADMIXTURES

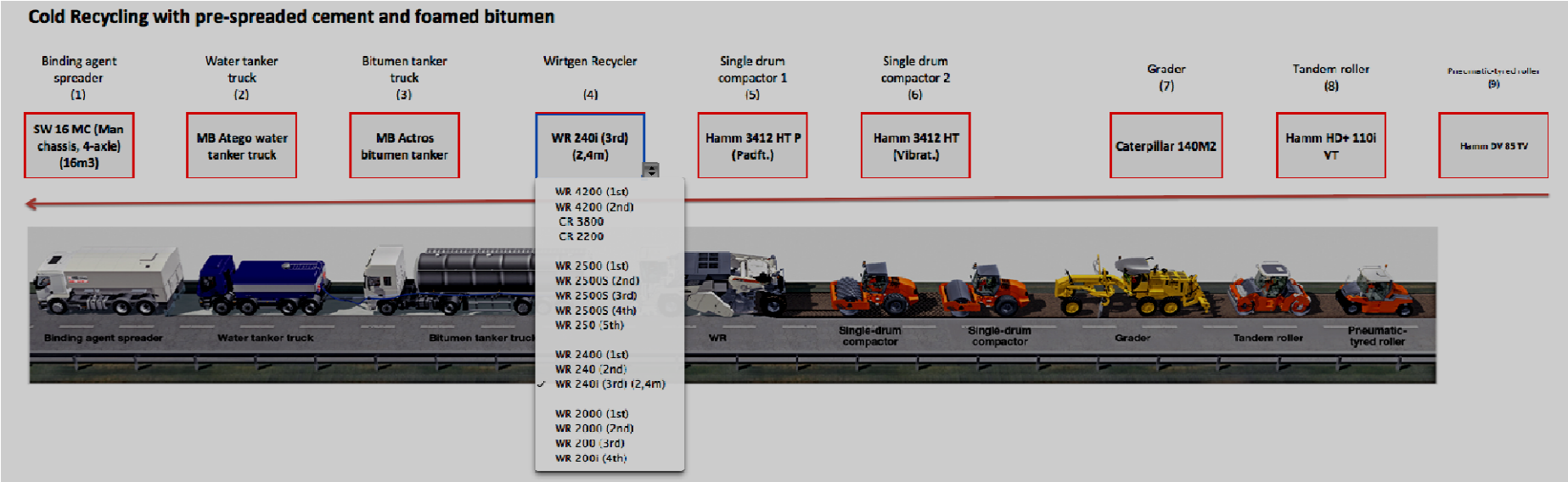
| | | | |
|---|---|---|---|
| Foamed bitumen: price [€/t] | 410 | Volume added [%] | 2,50 |
| Bitumen emulsion: price [€/t] | 393 | Volume added [%] | 2,50 |
| Water: price [€/m3] | 1 | Volume added [%] | 1,00 |
| Cement 32,5 R: price [€/t] | 72 | Volume added [%] | 0,50 |

# OptiRec – Example of material data


| Substance | Density ($t/m^3$) | $CO_2$ (kg/l) | Data source |
|---|---|---|---|
| Diesel – refining | 0.84 | 0.26 | Afteroilev |
| Diesel – consumption | 0.84 | 2.66 | Czech Ministry of Environment |

| Mix component | Density ($t/m^3$) | $CO_2$ (kg/t) | Data source |
|---|---|---|---|
| Water | 1.00 | 0.30 | IVL |
| Cement CEM II 32.5 R | 1.25 | 980 | IVL |
| Bituminous emulsion (C60B7) | 1.00 | 221 | Eurobitume |
| Foamed bitumen | 1.10 | 285 | Eurobitume |

# OptiRec – machine set selection

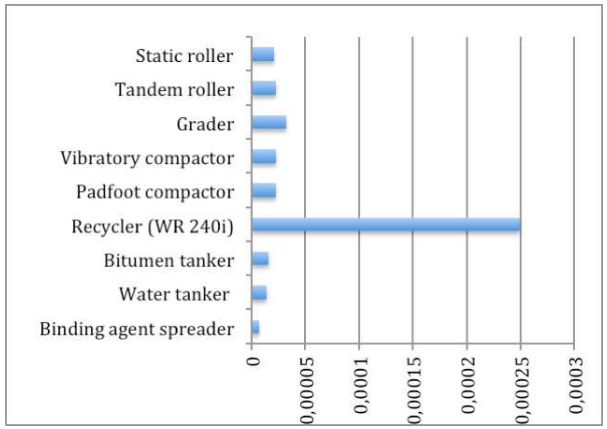



- CR (cold recycling) – foamed bitumen, cement
- CR (cold recycling) – foamed bitumen, cement slurry
- CR (cold recycling) – bitumen emulsion, cement
- CR (cold recycling) – bitumen emulsion, cement slurry
- CR (cold recycling) – foamed bitumen
- CR (cold recycling) – bitumen emulsion
- R (recycling) – cement
- R (recycling) – cement slurry
- Pulverization or Re-shaping

# OptiRec – machine set selection

## Average consumption of machines in the case study (l/m²)

| Construction machine | Fuel | Consumption (l/m²) | $CO_2$ (t/m²)* |
|---|---|---|---|
| Binding agent spreader | diesel | 0,0022 | 6.502E-06 |
| Water tanker | diesel | 0,0046 | 1.356E-05 |
| Bitumen tanker | diesel | 0,0052 | 1.520E-05 |
| Recycler (WR 240i) | diesel | 0,0788 | 2.302E-04 |
| Padfoot compactor | diesel | 0,0077 | 2.276E-05 |
| Vibratory compactor | diesel | 0,0077 | 2.276E-05 |
| Grader | diesel | 0,0109 | 3.204E-05 |
| Tandem roller | diesel | 0,0077 | 2.276E-05 |
| Static roller | diesel | 0,0070 | 2.071E-05 |




➡ average $CO_2$ production (t/m²)

# OptiRec – Results example

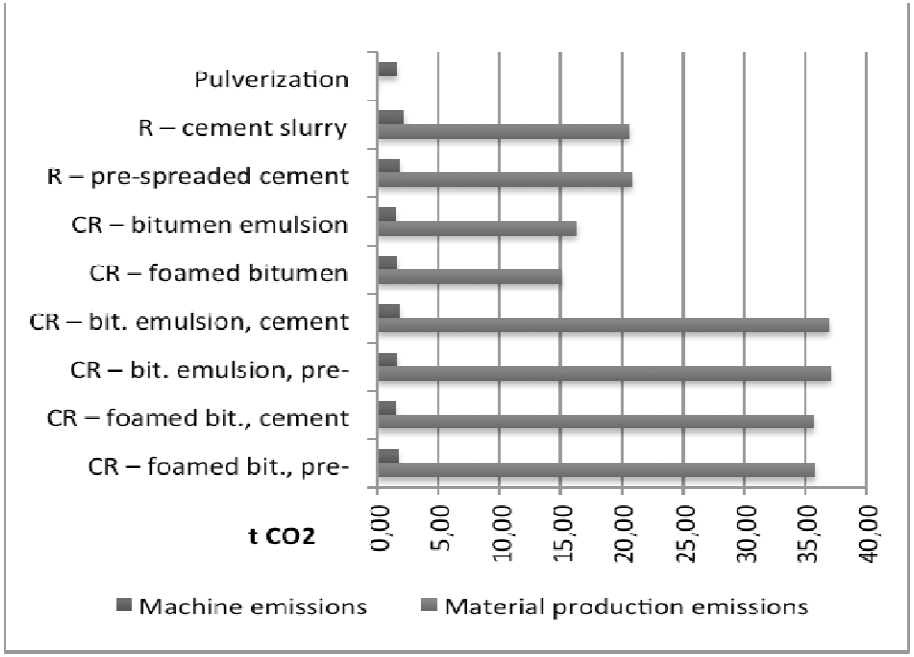
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1 | 2 | 3 | 4 |
| No. | Way of rebahilitation | Key machine | Price | Duration[h] | Energy [xx.] | CO2 [t] | HC+NOx (g/KWh) | CO (g/KWh) | PM (g/KWh) |
| 1 | Cold Recycling with pre-spreaded cement and foamed bitumen | Wirtgen WR 240 (3rd) | 24 199,45 € | 7,62 | | 19,7 | 3,92 | 6,24 | 0,04 |

| Machine | Total fuel and liquids cost [EUR] | Total machine cost (in) [EUR] | Total staff cost [EUR] | Total machine + Staff cost [EUR] | 2/3 Engine power [kW] | Idling Engine power [kW] | CO2 [t CO2] | Nox + HC [t] (cumulated) | CO [t] | Particles [t] |
|---|---|---|---|---|---|---|---|---|---|---|
| Wirtgen WR 240i (3rd) (2,4m) | 603,95 | 482,64 | 167,62 | **1254,20** | 447,00 | 135,00 | 1,1953 | 3,923 | 6,2413 | 0,0446 |
| StreuMaster SW 16 MC (MB Arocs 4136K 8x4 chassis, 4-axle) (16m | 17,16 | 17,57 | 19,16 | **53,89** | 275,00 | 50,00 | 0,034 | 0,581 | 0,3577 | 0,0048 |

| | Fuel consumption | | $CO_2$ production | |
|---|---|---|---|---|
| **Construction machine** | Average (l/h)* | Total (l) | Average (t/h)* | Total CO2 (t) |
| Recycler (WR 200, 3rd) | 50 | 517,360 | 0,151 | 1,511 |
| Recycler (WR 200i, 4rd) | 47 | 486,320 | 0,142 | 1,420 |
| Recycler (WR 2400, 1st) | 67 | 396,150 | 0,202 | 1,157 |
| Recycler (WR 2500S, 2nd) | 70 | 362,150 | 0,212 | 1,058 |

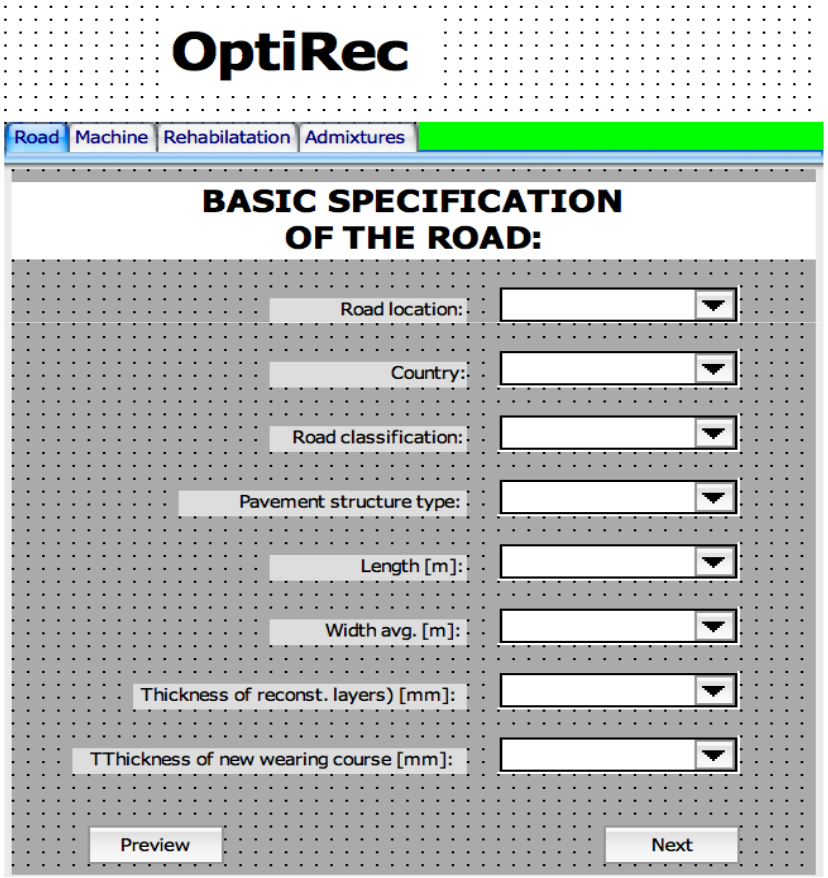
- Impact or recycler generations

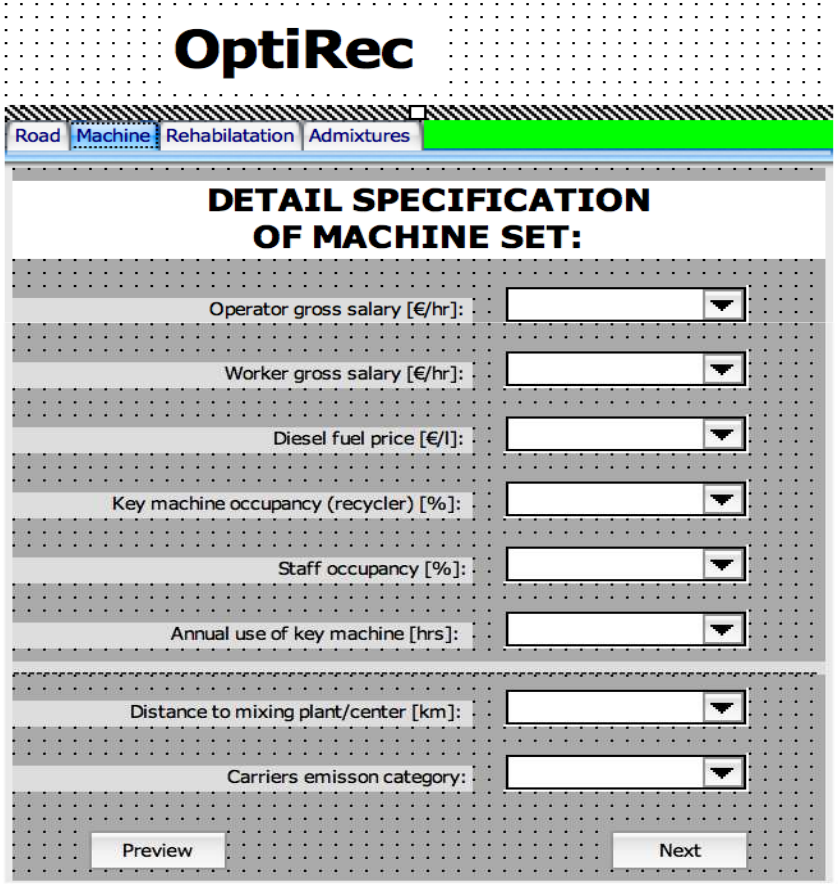
# OptiRec – Results example




- In case of road rehabilitation by using one of existing cold recycling technologies, there are 80-90 % of $CO_2$-emissions produced during the manufacturing of incorporated materials (RAP).
- Impact of used recycling machines of the road remains minor (10-20 %). This fact does not mean that it has an insignificant influence.
- Construction industry has primarily to look for avoiding emissions produced during production and processing of building materials by supporting re-use of once build-in materials.

# OptiRec – second generation – Visual Basic platform



# OptiRec – machinery catalogue

### 1.1. WIRTGEN WR 200i

**Obr. 1: Recyklér pro recyklaci za studena Wirtgen WR 200i**

Zdroj: Archiv autora

Samohybný recyklér Wirtgen WR 200i slouží pro recyklaci živičných vozovkových vrstev za studena. Lze jej využít i pro stabilizaci zemin.

Tento recyklér disponuje výkonnou silniční frézou a mísicím zařízením s možností připojení zásobníku či cisterny s asfaltovou emulzí či pěnoasfaltem. Tyto stroje se pomocí soustavy hadic spojují s recyklérem do sestavy a zajišťují mu kontinuální dodávku pojiva, které je vstřikováno přímo k mísicímu válci. V případě využití technologie recyklace s předem rozprostřeným cementem se k recykléru ještě připojuje zásobník či cisterna s vodou. Za recyklérem zůstává nově homogenizovaná asfaltová vrstva.

Díky kompaktním rozměrům není recyklér třeba přepravovat jako nadměrný náklad a je tedy vhodný i k použití pro krátkodobé práce.

Obsah

| Základní parametry: | | | |
|---|---|---|---|
| **Wirtgen WR 200i** | | | |
| Pracovní šířka: | 2000mm | Spotřeba na stavbě: | - |
| Tloušťka recyklované vrstvy: | 100 - 150 mm | Hmotnost: | 23 900 kg |
| Pracovní výkon: | až 800 m2/hod | Výkon motoru: | 320 kW |
| Pracovní rychlost (Ø): | 10 m/min | Emisní norma: | EURO 4 |

# OptiRec – working day snapshot

- day snapshot describes usual working day activities on the job site;
- machinery database including real-time data and site experience;
- four main activities/time sections have been identified:

1. **Cold crank (engine starting, heating up);**
2. **Net operation time (recycling);**
3. **Technical breaks (e.g. waiting for the connection of other machines in the defined and used machinery set);**
4. **Engine switched off (checking the machine – liquids, milling drum, safety, refuelling, filling water/cement tank).**

# OptiRec – working day snapshot

**Total non productive time (aprox. 25% of dayshift):**

**8 / 8 = 1 / 8 + 4 / 8 + 3 / 8**

**114 min = 14 min + 57 min + 43 min**

**Total time = Cold Crank (1x)+ Technical brake (3x) + Stop time (shut down)(2x**

| Time (min.) | Abbrev. | Description | Duration (min.) |
|---|---|---|---|
| DAY 1 | - | Begin - 1. working day | - |
| 0-34 | TB1 | Technical break 1 | 34 |
| 35-120 | R1 | Recycling - lane 1 - part 1 | 86 |
| 121-137 | TB2 | Technical break 2 | 17 |
| 138-223 | R2 | Recycling - lane 1 - part 2 | 86 |
| 224-241 | TB3 | Technical break 3 | 17 |
| 242-327 | R3 | Recycling - lane 2 - part 1 | 86 |
| 328-344 | TB4 | Technical break 4 | 17 |
| 345-431 | R4 | Recycling - lane 2 - part 2 | 86 |
| 432-465 | TB5 | Technical break 5 | 34 |
| - | - | End - 1. working day | 463 (7,75 h) |

**DETAIL**

| Chainage | Day 1 | Day 1 |
|---|---|---|
| 1200 m | **R2 = 86 min** Recycling | **TB2 = 19 min** Technical Break: (Iddle) |
| | **TB1 = 19 min** Technical Break: (Iddle) | **R3 = 86 min** Recycling |
| 600 m | **R1 = 86 min** Recycling | **TB3 = 19 min** Technical Break: (Iddle) |
| | **CC = 15 min** Cold crank: (Iddle) | **R3 = 86 min** Recycling |
| 0 m | **ST1 = 21 min** Stop time (Engine off): | **ST1 = 21 min** Stop time (Engine off): |

# OptiRec – Consultants and Sources

- Calculations supported by real life data from telematics of construction company (fuel consumption, daily usage);
- Real life data of emissions measured on site (during working process, during idling) - field emission laboratories;
- Truck dealers, trailer and fitting (prices, consumption data, truck technology, life cycle, maintenance);
- Mixing plant producers, owners and certification authorities (emission data);
- Engine producers - (consumption data);
- Construction company - foreman and managers - discussion about the real processing on site;
- Road administrators and public investors (road authorities).

## *N77 Hennebry's Cross to Ardaloo*
## - Followed project

- Comparison calculated OR data with real project
- Road rehabilitation via pavement cold recycling on site
- Basic data
  - Length: 1620 m
  - Width: 5,5 m
  - Rehab. depth - 250-300mm


- Technology: x mm existing pavement recycled to achieve a residual binder content x 2.2%, cement content of x% added, CRF excluded and total moisture content of x%.
- Key machine used
  - Road Recycler Wirtgen WR 2400

# Technology description – OptiRec input data

| Chainage | Description | Recycling technology |
|---|---|---|
| 0-200 | 300mm existing pavement recycled to achieve a residual binder content of 2.2%, cement content of 1.5% added, CRF excluded and total moisture content of 4%. | CR - bit. emulsion, cement (2 layer recycling) |
| 200-500 | 300mm existing pavement recycled (Pavement Option Type 1) to achieve a residual binder content of 3%, 1% cement content, 10% CRF and total moisture content of 4%. | CR - bit. emulsion, cement, agregate (2 layer recycling) |
| 500-700 | 300mm existing pavement recycled (Pavement Option Type 1) to achieve a residual binder content of 3%, 1% cement content, 10% CRF and total moisture content of 4%. | CR - bit. emulsion, cement, agregate (2 layer recycling) |
| 1690-1800 | 250mm existing pavement recycled to achieve a residual binder content of 2.2%; Cement content of 0%; CRF excluded from the mix, Total Moisture Content 4%. | CR - bit. emulsion, cement (2 layer recycling) |
| 1800 - 2020 | 250mm existing pavement recycled to achieve a residual binder content of 3%; Cement content of 1%; CRF 10%; Total Moisture Content 4% | CR - bit. emulsion, cement, agregate (2 layer recycling) |
| 2020 – 2450 | 250mm existing pavement recycled to achieve a residual binder content of 3%; Cement content of 1%; CRF 10%; Total Moisture Content 4%. | CR - bit. emulsion, cement, agregate (2 layer recycling) |
| 700 – 970 | 300mm existing pavement recycled + 10% CRF + 1% Cement + Foam mix – Binder 125 Pen | CR - foamed bit., cement, agregate (2 layer recycling) |
| 970-1180 | 300mm existing pavement recycled + 10% CRF + 1% Cement + Foam mix – Binder 125 Pen. | CR - foamed bit., cement, agregate (2 layer recycling) |
| 1180-1400 | 300mm existing pavement recycled + 10% CRF + 1% Cement + Foam mix – Binder 125 Pen. | CR - foamed bit., cement, agregate (2 layer recycling) |
| 1400-1620 | 300mm existing pavement recycled + 10% CRF + 1% Cement + Foam mix – Binder 125 Pen. | CR - foamed bit., cement, agregate (2 layer recycling) |

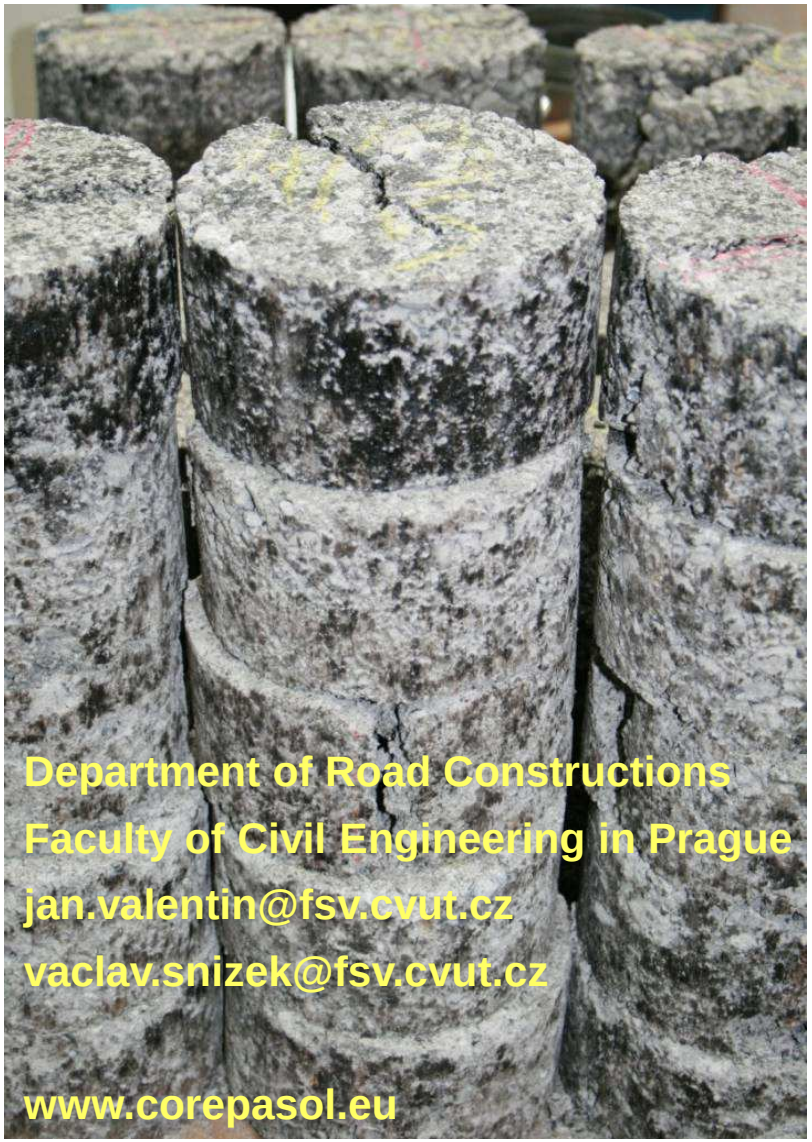
# Fuel consumption on project
# - Job site data vs. OptiRec calculation

Key machine: recycler Wirtgen WR 2400

| Chainage | Project Consumption (job site data) (l) | OptiRec fuel consumption on project (l) 2/3 Charge | OptiRec fuel consumption on project (l) full Charge |
|---|---|---|---|
| 0-200 | 340 | 554 | 827 |
| 200-500 | 450 | 831 | 1241 |
| 500-700 | 347 | 554 | 827 |
| 1690-1800 | 173 | 305 | 455 |
| 1800 - 2020 | 660 | 610 | 910 |
| 2020 – 2450 | 1050 | 1192 | 1778 |
| 700 – 970 | 620 | 748 | 1117 |
| 970-1180 | 1025 | 582 | 869 |
| 1180-1400 | 971 | 610 | 910 |
| 1400-1620 | 990 | 610 | 910 |
| TOTAL | 6626 | **6595** | **9844** |

CoRePaSol
characterization of advanced cold recycling bitumen stabilized pavement solutions

CESTI centre for effective and sustainable transport infrastructure

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