EUROPEAN CONCRETE PAVING ASSOCIATION

Sustainability and Resilience in the heart of concrete roads

CONTENTS

Everyone today is aware of the global challenges facing our society. The concept of "sustainable construction" has been at the heart of the construction world for many years, focusing on the three well-known pillars: economy, environment and society. With the issue of global warming, the debate is now more focused on reducing CO_2 emissions with a roadmap towards complete decarbonisation by 2050.

SUSTAINABILITY = meeting the needs of the present without compromising the ability of future generations to meet their own needs (UN, 1987)

This certainly applies to the transport sector and therefore also to the road construction sector. Indeed, roads and road transport will continue to play an important role in moving people and goods in the future. For freight transport in particular, a further significant increase is expected in the coming decades and thus also a possible increase in environmental impact. Additional measures will therefore be necessary and decision-makers will have to make thoughtful and considered choices in the design, construction and management of transport infrastructure. The choice of the type of road pavement is one such choice, where the aim should be to find the most sustainable solution, taking into account all possible criteria, both in the short and long term.

Even if the focus is mainly on measures to combat global warming, there are other important aspects that need to be taken into account and are also high on the European Union's agenda. These include the circular economy, the resilience of our infrastructure and sensible water management.

- Circular construction is about saving resources through prevention, re-use and recycling.
- Resilient roads must be able to withstand increasing threats of natural and man-made disasters. Sustainability and resilience work in tandem, with resilience forming the foundation for all three pillars of sustainability.
- An ecological water management requires an integrated approach throughout the water chain to mitigate both problems of flooding and water shortage during periods of drought.

RESILIENCE = 'the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation (IPCC, 2014)

The European Concrete Paving Association, EUPAVE, is convinced that rigid solutions – concrete pavements and hydraulically bound base layers - can contribute to a more sustainable and resilient transportation network. Therefore, EUPAVE's Sustainability & Resilience Working Group has prepared 6 fact sheets covering the different themes. The work started with an infographic "Concrete pavements make roads more sustainable", showing the basic messages in the different domains. Next, the fact sheets were drafted in which each sub-aspect was discussed in more detail, each time based on the latest findings from international practice and research.

The following factsheets are available in this publication:

- Concrete roads can strongly contribute to reduction of CO_2 emissions from road transport – HIGH ALBEDO.
- Concrete roads can strongly contribute to reduction of CO_2 emissions from road transport – LESS FUEL CONSUMPTION.
- Concrete roads are made with local raw materials, offer a long service life and are 100% recyclable – 100% RECYCLING.
- Concrete roads are made with local raw materials, offer a long service life and are 100% recyclable – LONG SERVICE-LIFE – LOW LIFE-CYCLE IMPACT AND COST – LOW MAINTENANCE, LESS DISRUPTION.
- Concrete roads show better resilience to climate change and extreme meteorological events – HIGHER RESILIENCE.
- Concrete contributes to more ecological water cycle management – SUSTAINABLE WATER MANAGEMENT.

EUPAVE will continue to defend the importance of a holistic approach over the entire life cycle of the road, both for overall costs, environmental impact considering all environmental indicators and social aspects. The longevity of concrete roads plays a vital role in this respect, which should not be lost sight of and not be countered by short-term benefits that lead to a negative impact in the longer term. The resilience of the road infrastructure is also becoming increasingly important and still difficult to separate from sustainability. It is crucial that decision-makers are aware of the importance of this life-cycle approach to come to the most responsible choice. Together we can achieve a highly performing, sustainable, carbon-neutral and resilient road network.

EUPAVE
EUROPEAN CONCRETE PAVING ASSOCIATION

FACT SHEET
High albedo

Concrete roads can strongly contribute to reduction of CO_2 emissions from road transport

Albedo is the ability of a surface to reflect light rays. In case of a light-coloured concrete surface (high albedo: 0.20 to 0.40), more energy is reflected in the atmosphere compared to a black surface (lower albedo: 0.05 to 0.15), which absorbs the heat.

The high albedo of concrete pavements offers several benefits:

1. Slowing down the global heating

Changing 1m² of black asphalt surface into a light concrete helps countering the climate change as if **22.5 kg CO_2** was not emitted. That is enough to off-set **30 to 60%** of the CO_2 emitted during the manufacturing process of the cement used in that concrete pavement.

2. Reducing the Urban Heat Island Effect (UHIE)

UHIE is the warming effect that occurs in large metropolitan areas. Light-coloured pavements have lower heat absorption; they limit the harmful impacts of UHIE by a reduction of the ambient temperature, the number of extreme heat days and the likelihood of smog.

3. Saving cost and energy for road lighting

Road lighting designers base themselves on the reflected light as it is perceived by the driver of a vehicle. The superior reflectivity of concrete makes it possible to achieve savings by placing fewer lighting columns or by using lamps of a lower luminance. In both cases costs can be reduced up to 35%, either by the lower number of lighting columns or by reduced lighting power, both resulting in less electricity consumption.

4. Offering a better visibility

When road lighting is not available, the light coloured surface of a concrete road still offers a better visibility, especially in difficult circumstances when visibility plays an important role: at night and in bad weather conditions such as heavy rain or dense fog.

SOME MORE INFORMATION

WHAT IS ALBEDO?

The ability of a surface to reflect light rays (and therefore energy) is determined by its "albedo". It is the ratio of the reflected to the incident light or radiation. The higher the albedo, the more energy is reflected back into space, out of the atmosphere. On average the albedo of planet earth is 0.30 That is to say 30% of all the solar energy is reflected while 70% is absorbed. As a result, the average temperature at the earth's surface is 15° C. Polar ice with its high albedo plays an important role in maintaining this temperature balance. Should the polar ice melt the average albedo of the earth will fall because the oceans will absorb more heat than the ice. The temperatures on earth will rise and global warming will accelerate.

Table 1: Values of light reflection or albedo for different materials

SURFACE	ALBEDO
Fresh snow	0.81 – 0.88
Old snow	0.65 – 0.81
Ice	0.30 – 0.50
Rocks	0.20 – 0.25
Wood	0.05 – 0.15
Soil/Ground	0.35
Concrete	0.20 – 0.40
Asphalt	0.05 – 0.15

SLOWING DOWN THE GLOBAL WARMING

Surfaces with a higher albedo reflect more radiation and increase the outgoing radiation at the top-of-atmosphere. In this way they have the potential to alter the earth's energy balance and consequently also the climate change effects. This effect can be expressed in the form of a capture or release of CO_2, since greenhouse gases and surface albedo are both forcing agents that can have an impact on the climate.

Several scientific studies have calculated the impact of changing a pavement from asphalt to concrete, from a darker to a lighter surface. This increase of albedo, estimated at an average of 15%, can be modelled as a capture of CO_2 with an equivalent radiative forcing effect. This equivalence, for the most conservative results, taking into account cloud cover and other reducing factors, amounts to 1.5 kg/m^2 per Δ albedo of 0.01. For a Δ albedo of 0.15 the total equivalent "50 years GWP" savings are 22.5 kg CO_2/m^2 of pavement. That is a great amount, enough to offset 30 to 60% of the CO_2 emissions needed for the cement production (fuel burning + calcination) of that pavement! (Figures depend on the thickness of the pavement, the cement content of the concrete mix and the cement type)

REDUCING THE URBAN HEAT ISLAND EFFECT (UHIE)

Because of the global climate change, more and more extreme weather situations occur. It has been observed that during warm periods, the temperature in an urban environment is higher than the surrounding rural area. This phenomenon is called the Urban Heat Island (UHI) effect. It is explained by the calorific absorption during the day by the materials used in an urban environment. That heat is released during the evening and overnight, leading to a rise of the ambient temperature. The UHIE increases the energy demand during summer because of a higher use of air conditioning; it also reinforces the greenhouse gas effect and it leads to a higher risk on smog and air pollution, with negative impact on public health.

The increase of periods of heat waves will enhance the UHIE in the future. It is therefore appropriate to take measures to prevent this phenomenon in urban planning policy. The use of "cool pavement" surfaces is one of them. These can be light-reflecting (high albedo) and/or evaporative pavements such as pervious surfaces and vegetated permeable pavements.

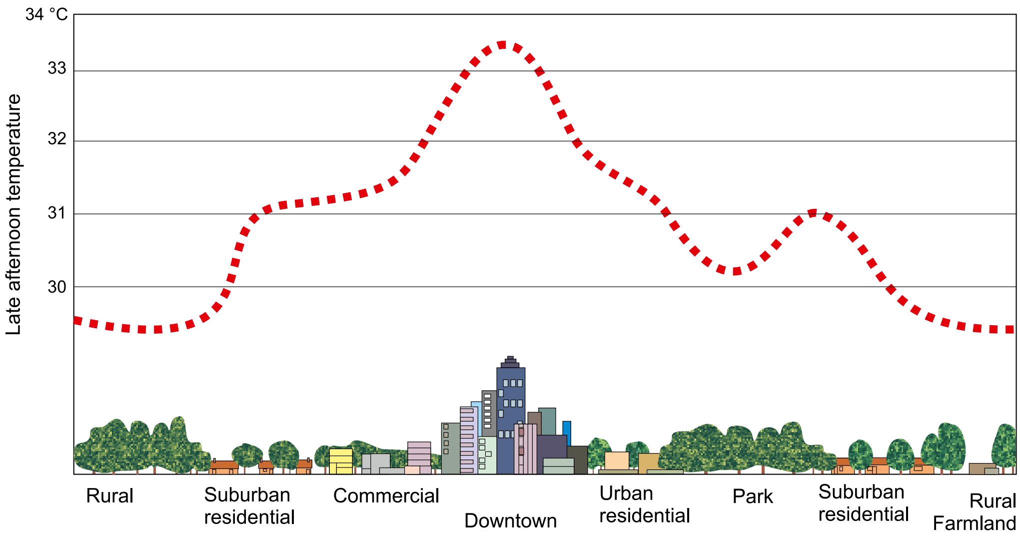


Figure Urban Heat Island Effect © EPA, U.S.

The lower calorific absorption of light surfaces such as concrete also contributes to the reduction of the heat island effect. The picture below shows a thermal image of an asphalt and concrete surface located next to each other. The measurement was carried out in August 2007 at about 17:00h on a slightly cloudy day and the temperature difference between the two road surfaces was about 11° C. Research has indicated a general average decrease of the urban heat island intensity of 0.4° C.

Another type of cool surface consists of permeable pavements with a structure that allows storing water. The evaporation of the surface water subtracts heat from the pavement, as it is the case with vegetated surface. In this context, the combination of a permeable surface and vegetated pavement is advantageous. Obviously that kind of pavements are aimed in the first place at retaining the water in situ and allowing it to infiltrate and so they already contribute considerably to sustainable water management.

The "cool pavements" strategy is supported by the DG Environment of the European Commission and the US Environmental Protection Agency. It is now up to the project leaders to take into account the Urban Heat Island effect in a contemporary vision of roads and urban public spaces. The integration of light-coloured concrete surfaces and/or permeable pavements into the concept can also be carried out in compliance with the aesthetic requirements. There are already many examples and sources of inspiration for such applications all around the world.

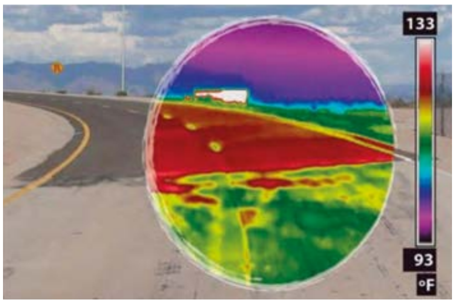
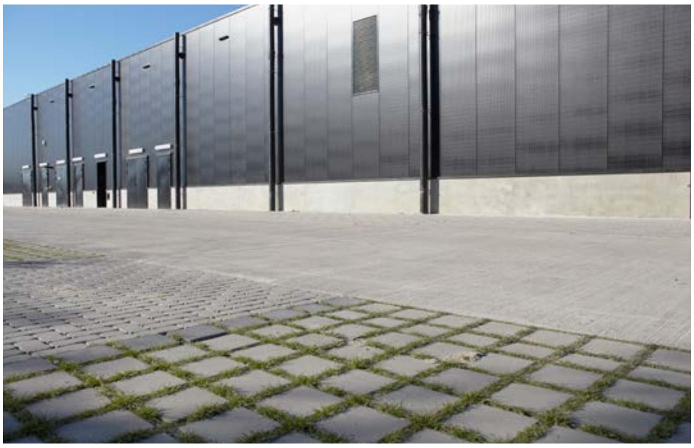


Figure showing a thermal image of a concrete-asphalt coating © ACPA, U.S.

Brussels, Atomium square © L. Rens / FEBELCEM

Brussels, Rogier square © L. Rens / FEBELCEM

Malaga Marina © L. Rens / FEBELCEM



Beringen B Mine © A. Nullens / FEBELCEM

SAVING COST AND ENERGY FOR ROAD LIGHTING

The superior reflectivity of concrete makes it possible to achieve savings in the costs of lighting streets and motorways. Designers of road lighting make their calculations indeed based on 'luminance', which is the reflected light in the direction of the observer. Savings can be achieved by placing fewer lighting columns or by using lamps of a lower luminance. In both cases costs can be reduced, primarily by being able to cut back on the number of lighting columns required and secondly in annual electricity consumption. Savings around 30 to 35% are being reported, both for lighting equipment and energy.

A Canadian study shows for example that whereas 14 lighting columns are required for a distance of one km of concrete carriageway, an asphalt road requires 20 lighting columns to achieve the same level of lighting.

OFFERING A BETTER VISIBILITY

When road lighting is not available, the light coloured surface of a concrete road still enhances visibility in difficult circumstances: at night and in bad weather conditions such as heavy rain or dense fog. Better visibility contributes to traffic safety.

E34-A11, Belgium
© L. Rens / FEBELCEM

More environmental benefits from concrete roads can be found on EUPAVE's infographic "Concrete Pavements Make Roads More Sustainable" (2019), https://www.eupave.eu/resources-files/infographic

References

Akbari, H., Menon, S., Rosenfeld, A. (2009). Global cooling: Increasing world-wide urban albedos to offset CO2 . Climatic Change, 94(3–4), 275–286.

Akbari, H., Damon Matthews, H., Seto, D. (2012). The long-term effect of increasing the albedo of urban areas. Environmental Research Letters, 7(2).

CSHub. (2019). Albedo: A measure of surface reflectivity

http://ec.europa.eu/environment/integration/research/newsalert/pdf/cool_pavements_reduce_urban_heat_islands_state_of_technology_450na3_en.pdf

https://www.epa.gov/heat-islands/using-cool-pavements-reduce-heat-islands

https://www.epa.gov/heat-islands/heat-island-compendium

Li, H., Harvey, J., Kendall, A. (2013) Field measurement of albedo for different land cover materials and effects on thermal performance. Building and Environment 59 (2013), 536-546

Millstein, D., Menon, S. (2011). Regional climate consequences of large-scale cool roof and photovoltaic array deployment. Environmental Research Letters, 6(3).

NRMCA. Luminance, illuminance and concrete pavement. Promotion facts brochure 1.

Pomerantz, M., Bon, P., Abkari, H., Chang, S.-C. (2000) The effect of pavements' temperatures on air temperatures in large cities. Heat Island Group, Lawrence Berkeley National Laboratory, Berkely, Canada.

Rens, L. (2009). Concrete roads: a smart and sustainable choice. EUPAVE

Sen, S., Roesler, J. (2019) Coupled pavement-urban canyon model for assessing cool pavements. Proceedings of the International Conference on Airfield and Highway Pavements 2019, Chicago, Illinois, 2019.

Xu, X., Gregory J., Kirchain, R. (2017). Evaluation of the Albedo-induced Radiative Forcing and CO2 Equivalence Savings: A Case Study on Reflective Pavements in Four Selected U.S. Urban Areas,

EUPAVE
EUROPEAN CONCRETE PAVING ASSOCIATION

FACT SHEET
Less Fuel Consumption

Concrete roads can strongly contribute to reduction of CO_2 emissions from road transport

Fuel consumption is not only influenced by the vehicle (type of engine, aerodynamic profile, tyres...) but also by the pavement it is driving on. The factors related to the surface of the pavement are the evenness, the surface texture and the deflection.

While texture and evenness can be made the same for asphalt and concrete roads, this is not the case for deflection.

Several researches indicate around **2% fuel savings** for trucks driving on concrete pavements compared to asphalt. This was found both in theoretical studies (by MIT) and in field tests.

The differences are higher for **slower traffic speeds** and for **higher outside temperatures.**

When calculating a LCA for a motorway, reduced greenhouse gas emissions due to lower fuel consumption should be taken into account in the use phase of the pavement, together with other influencing factors. Based on data of the European road transport network, changing from flexible asphalt to rigid concrete creates **over 50 years a difference in GWP (Global Warming Potential) estimated to be 78 kg CO_2/m^2** of pavement, more than offsetting its own CO_2.

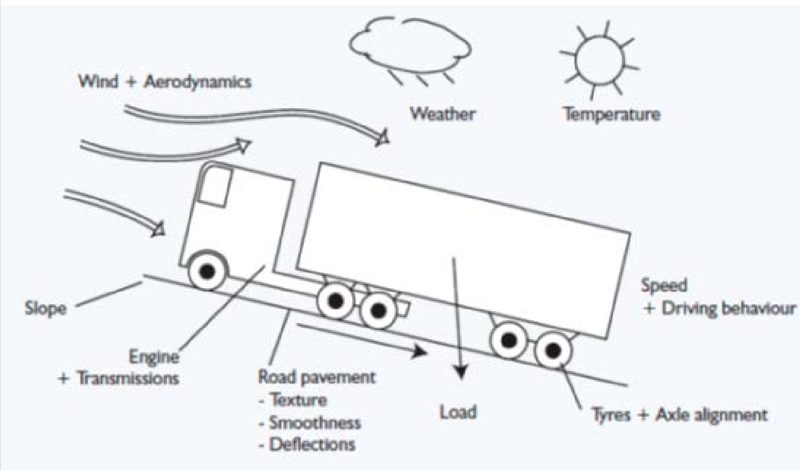
Considering the total motorway network and freight road transport in Europe, there is a total potential of saving **2.5 million tonnes of CO_2 per year.**

In addition, reduced fuel consumption also means **less pollution** and **less operating costs** for truck transport companies.

SOME MORE INFORMATION

Not only electrical vehicles but also the physical road infrastructure can contribute to the reduction of CO_2 emissions by road transport. Indeed, several studies and researches have shown a lower fuel consumption of heavy vehicles on rigid, concrete pavements compared to flexible, asphalt pavements.

There are many factors influencing the fuel consumption of a vehicle. Some of them are related to the vehicle and its engine or to the resistance of the vehicle due to aerodynamics or the slope of the pavement. **The factors related to the surface of the pavement are the evenness, the surface texture and the deflection.**



Evenness and texture depend on the quality of construction and/or safety requirements, both for concrete and asphalt roads. This includes the absence of undulations, uneven patches, rutting, potholes or deteriorated joints.

Deflection, however, depends mainly on the stiffness of the pavement and that is the big difference between concrete and asphalt.

The deformation (not at scale) of an asphalt road under a wheel load has the same effect as a vehicle driving uphill, requiring more energy, fuel and CO_2.

The effect of a deflected pavement under a wheel load is the same as if the vehicle would constantly drive uphill and would consequently consume more fuel and emit more CO_2. Concrete pavements are rigid structures, which show less deflection under heavy traffic and thus less fuel is consumed and less CO_2 emitted.

Some of the most relevant studies and researches indicate the following results:

• FIELD RESEARCH BY THE NATIONAL RESEARCH COUNCIL OF CANADA

A series of four investigations was conducted on various types of roads and vehicles, in different seasons and using different statistical models. The final and most complete research measured fuel consumption, both for an empty and full tractor–trailer unit, on concrete and asphalt roads with equal degree of roughness (or unevenness). This means that only the impact of surface texture and pavement deflection were counted. The results ranged from 0.8 to 3.9% with a reliability of 95%.

• FIELD RESEARCH BY THE SWEDISH NATIONAL ROAD AND TRANSPORT INSTITUTE (VTI)

VTI also investigated the impact of pavement type on fuel consumption by measurements on a motorway north of Uppsala, Sweden, where a motorway included both asphalt and concrete pavements. For a passenger car – Volvo 940 – the measurement showed 1.1% less fuel consumption on the concrete pavement compared to the asphalt pavement. The results were found to be statistically significant and can mainly be attributed to differences in surface texture (stone mastic asphalt versus brushed concrete, both with an aggregate size of 16mm. The measurements with a heavy goods vehicle – a four axle Scania R500 + three axle trailer, total weight 60 tonnes at a speed of 80 km/h – showed an average of 6.7% less fuel consumption on the concrete pavement compared to the asphalt pavement. In this case both texture and deflection have impacted the results of the field tests.

• FIELD RESEARCH BY FLORIDA INTERNATIONAL UNIVERSITY

Statistical results from two field studies both show fuel savings on rigid pavement compared to flexible pavement with the test conditions specified. The savings derived from a first phase were 2.50% for a passenger car at 112 km/h, and 4.04% for 18-wheel tractor-trailer at 93 km/h. The savings resulted from a second phase were 2.25% and 2.22% for passenger car at 93 km/h and 112 km/h, and 3.57% and 3.15% for the 6-wheel medium-duty truck at 89 km/h and 105 km/h. All savings were statistically significant at 95% confidence level and were assumed to depend on differences in both deflection and texture.

• THEORETICAL MODELLING BY MIT

These studies were based on a theoretical model of the pavement-vehicle interaction and aimed at quantifying the deflection of the pavement, which was then used for estimating the impact on fuel consumption. In the second phase of the research, temperature and speed effects were included and a desktop experiment was set up to verify the theoretical results. The differences in fuel consumption showed a wide range, as indicated in the following table.

The difference of the average fuel consumption is **0.8233 litres/100 km or around 2.35%** (taking into account an average fuel consumption of 35 litres/100 km). This is the same magnitude as found in the Canadian field tests.

• THEORETICAL MODELLING BY IFSTTAR

In this model, the deformation, due to the viscoelastic behaviour of an asphalt pavement and its effect on fuel consumption was also studied. The energy dissipation was highest for high temperatures and slow speed and could amount up to 0.5% of the total energy of the fuel.

	LOW VALUE	AVERAGE VALUE	HIGH VALUE
Asphalt	0.21	1.07	6.25
Concrete	0.07	0.25	0.50
Delta	0.14	**0.82**	5.75

Fuel consumption (litre/100 km) due to deflection of the pavement by heavy truck traffic [Akbarian, M. (2015)]

The results of both field tests (National Research Council of Canada) and theoretical studies (MIT) show differences in fuel consumption, for heavy vehicles on concrete roads compared to asphalt roads, of around **2%**. High temperatures and low speeds make the differences higher. In urban environments or on congested motorways, where traffic is slow, the deflection will play a greater role compared to the impact of unevenness.

But even with small differences in fuel consumption, this parameter should not be neglected as it can significantly impact the results of an LCA of a road pavement, particularly for roads with intense and heavy traffic.

When calculating a LCA for a motorway, reduced greenhouse gas emissions due to lower fuel consumption should be taken into account in the use phase of the pavement, together with other influencing factors.

Based on average data of the European road transport network (80 000 km of motorway – annual freight road transport of 1804 billion tonnes-kilometres - an average payload of 16 tonnes - changing 2 slow lanes and hard shoulder, with a width per carriageway of 10 m, from a flexible asphalt to a rigid concrete structure), the **difference in GWP over 50 years can be estimated to be 78 kg CO_2/m^2 of pavement** or a **total potential of saving 2.5 million tonnes of CO_2 per year.**

In addition, reduced fuel consumption also means **less pollution** and **less operating costs** for truck transport companies.

More environmental benefits from concrete roads can be found on EUPAVE's infographic "Concrete Pavements Make Roads More Sustainable" (2019), https://www.eupave.eu/resources-files/infographic

References

Akbarian, M. (2015) Quantitative sustainability assessment of pavement-vehicle interaction: from bench-top experiments to integrated road network analysis. Doctoral thesis at MIT, Cambridge, Massachusetts, U.S.A.

Akbarian, M., Ulm, F.-J, Xin-Xu, Kirchain, R., Gregory, J., Louhghalam, A., Mack, J. (2019) Overview of pavement life cycle assessment use phase research at the MIT Concrete Sustainability Hub.

Chupin, O., Piau, J.-M. & Chabot, A. (2013) Evaluation of the Structure-Induced Rolling Resistance (SRR) for Pavements Including Viscoelastic Material Layers. Materials and Structures, 6(4), p. Springer Netherlands.

EUPAVE (2011). Concrete pavements contribute to decarbonising of transport.

https://ec.europa.eu/eurostat/statistics-explained/index.php/Road_freight_transport_by_journey_characteristics#Average_vehicle_loads

Hultqvist, B.-A. (2010) Measurements of fuel consumption on an asphalt pavement and a concrete pavement in Sweden. Proceedings of the 11th International Symposium on Concrete Roads, Seville, Spain.

Jiao, X. (2015) Effect of pavement-vehicle interaction on highway fuel consumption and emission. Doctoral thesis at Florida International University, Miami, Florida, U.S.A., FIU Electronic Theses and Dissertations. 2251.

Mack, J., Akbarian, M., Ulm, F.J.,Louhghalam, A. (2018) Proceedings of the 13th International Symposium on Concrete References Roads 2018, Berlin, Germany

EUPAVE
EUROPEAN CONCRETE PAVING ASSOCIATION

FACT SHEET
100% Recycling

Concrete roads are made with local raw materials, offer a long service life and are 100% recyclable

Concrete pavement recycling – motorway E17, De Pinte, Belgium, 2011 © L. Rens / FEBELCEM

Concrete is made with **local raw materials** and is **100% recyclable**. Concrete having reached the end of its life can be crushed to provide aggregates – sand and stones – for use in new concrete or in other cement-bound or unbound applications such as road bases. In all cases **natural resources are saved**.

Concrete mixes for road construction can accommodate **low carbon cement** types using secondary materials (fly ash, slag) recycled from other industries, resulting in **equal performances**.

A selective demolition and recycling allows to separate the high quality recycled concrete aggregates (RCA), e.g. coming from pavements, from the normal RCA (e.g. coming from foundations and buildings).

High quality RCA can be reused in concrete for new pavements, other infrastructure or buildings. Thanks to research and technical developments, the number of applications is growing, both for pavements and for kerbs, gutters and safety barriers.

The normal quality RCA are mostly used to produce high performing base layers, which are indispensable for long-life pavements, both asphalt and concrete. This is a good example of open loop recycling and it is often the most sustainable way to reuse these aggregates.

RCA can reabsorb from the atmosphere up to 20% CO_2 of the originally emitted CO_2 during the cement manufacturing. This is called (re)carbonation. It improves the quality of the RCA, making them even more suitable for reuse in new concrete.

The research project "Fastcarb" studies how this process can be accelerated.

Finally, new techniques of "smart crushing" allow for a better separation of aggregates and hardened cement paste in crushed concrete. This results in a better quality of the stones and allows reuse of the recycled cement, either in the cement manufacturing process or directly in the concrete mix.

SOME MORE INFORMATION

RECYCLABILITY

About 450-500 million tonnes of construction and demolition waste (C&DW) is generated every year in Europe, at least a third of which is concrete. Fortunately for concrete, recycling is not technically difficult. Concrete can be 100% recycled after demolition!

Recycling concrete offers two main benefits: it saves primary raw materials and reduces the amount of waste sent to landfill. There are two main ways in which recycled concrete is reused:

- As a recycled aggregate in new concrete
- As a recycled aggregate in road bases and earthworks. The base layers can be either unbound aggregates or cement-bound (cement-treated base, lean concrete…).

It is clear that concrete production generates higher requirements on the recycled materials than e.g. unbound base layers. That is why recycled concrete aggregates (RCA) of high quality, e.g. coming from old concrete pavements, are used for replacing virgin aggregates in new concrete. Most of the applications so far consisted of the use of RCA (mostly 60%, sometimes up to 100% of the coarse aggregates) in the bottom

Motorway construction in two-layer jointed plain concrete in Austria © Smart Minerals GmbH layer of a two-layer jointed concrete pavement. This is typically the Austrian motorway construction practice since 1990. Nowadays, thanks to further research and technical developments, the number of applications is also growing in one-layer pavements, as well as in kerbs, gutters and safety barriers.

RCA of normal quality, coming from CDW (other than pavements) can possibly contain higher amounts of brick, glass or other materials. Their use is only allowed for certain types of concrete of lower strength classes. They can also be used to produce high performing unbound or cement-bound base layers, which are indispensable for long-life pavements, both asphalt and concrete. This is a good example of open loop recycling and it is often the most sustainable way to reuse these aggregates.

It also shows the importance of a high performing selective demolition and recycling strategy in order to separate the high quality RCA from the normal quality.

Another essential parameter is transport distance. Due to the large share of coarse aggregates in concrete, LCA results are influenced to a relatively large extent by changes in transport distance of the aggregates. Local availability is therefore indispensable.

As a conclusion, the choice of application should be based on the optimum balance of sustainability, local availability and long-term technical performance.

RECARBONATION

Cement recarbonation refers to the process where CO_2 is re-absorbed by the hardened concrete. Carbonation is a slow process that occurs in concrete where lime (calcium hydroxide) in the cement paste reacts with carbon dioxide from the air and forms calcium carbonate. For pavements, this is a very slow process during their service life because of the high quality of that concrete. The amount of absorbed CO_2 is only about 0.5 to 1 kg/m^2 of pavement.

At the end of their useful life, buildings and infrastructure (reinforced concrete structures) are demolished. If the concrete is then crushed, its exposed surface area increases and this increases the recarbonation rate. The amount of recarbonation is even greater if stockpiles of crushed concrete are left exposed to the air prior to reuse. In order to benefit from the CO_2 trapping potential, crushed concrete should be exposed to atmospheric CO_2 for a period of several months before its reuse. This needs to be taken into account in the way construction waste is dealt with. Up to 20% of the originally emitted CO_2 during the cement manufacturing can be reabsorbed, when proper recycling practices are applied.

The FastCarb research project (www.fastcarb.fr 2018-2020) aims at accelerating the carbonation process by using CO_2 at higher temperature and pressure. It consists of an experimental approach in the laboratory and an implementation at industrial scale.

In addition carbonation has another advantage: it improves the quality of the treated aggregates by plugging the porosity, making them even more suitable for reuse in new concrete.

SMART CRUSHING

Recycling methods have been investigated which allow separating the hardened cement paste from the original aggregates. By eliminating that hardened cement paste, RCA gets the same characteristics as virgin aggregate with similar impact on concrete characteristics such as strength, E-modulus, shrinkage and creep. One of the methods to separate the cement paste was developed in the Netherlands. It is a "smart crusher" with crushing jaws moving in two directions. In that way the crushed concrete is separated in different fractions of powder, sand and stones. As a result the obtained new aggregates are much cleaner and can perfectly be reused in new concrete.

In addition the fine particles obtained can be used as a secondary raw material in clinker production, as a resource for blended cements or as a filler directly in the concrete mix.

Crushing and sieving installation at motorway N49, Zwijndrecht, Belgium, 2007 © AWV, Flemish Agency for Roads and Traffic

More environmental benefits from concrete roads can be found on EUPAVE's infographic "Concrete Pavements Make Roads More Sustainable" (2019), https://www.eupave.eu/resources-files/infographic

References

https://circulareconomy.europa.eu/platform/en/good-practices/cement-recarbonation

https://fastcarb.fr/en/home/

Lagerblad, B. (2005). Carbon dioxide uptake during concrete life cycle – State of the art. Swedish Cement and Concrete Institute. CBI Report2:2005, Stockholm

Müller, C., Palm, S., Reiner, J. (2015). Closing the loop: what type of concrete re-use is the most sustainable option? European Cement Research Academy, Technical Report A-2015/1860, Düsseldorf

Recarbonation. The view of the cement sector. (2020). CEMBUREAU, Doc 17540/JR/SL

Rens, L. (2009). Concrete roads: a smart and sustainable choice. EUPAVE

Un béton "vert" est-il possible? (Is a « green » concrete possible?) (2020). IFSTTAR, article published in the magazine N° 86 BETON[S], January-February 2020.

van der Wegen, G. (2020) Een overzicht van innovatieve recyclingsmethoden (An overview of innovative recycling methods). Article in the Dutch professional magazine BETONIEK-Vakblad 1/2020.

EUPAVE
EUROPEAN CONCRETE PAVING ASSOCIATION

FACT SHEET
Higher Resilience

Concrete roads show better resilience to climate change and extreme meteorological events

© National Weather Service, U.S.

One of the aspects of climate resilience is the capacity of a system to absorb stresses and remain functional in the face of external stresses imposed upon it by climate change.

For roads and infrastructure, climate resilience efforts aim to address vulnerability to the environmental consequences of climate change.

The two main consequences of climate change that will affect roads are the increases in temperature and precipitation. Europe's road network is expected to undergo various stresses as a result: flooding, erosion of embankments and foundations, loss of road structure integrity and loss of pavement integrity. Therefore, an appropriate adaptation strategy and a preventive long-term approach are necessary, providing robust, 'future-proof' solutions.

All types of concrete roads are long-lasting and are built to withstand changes in temperature or moisture. Concrete stiffness remains constant in the range of ambient temperatures. It does not suffer softening or rutting and no hazardous pollutants are emitted at high temperature. Thanks to its fire resistance, concrete stands up to the heat of forest fires. Concrete surfaces keep their properties over time and show no risk of delamination. In addition, cement bound base layers are high quality, erosion- and frost-resistant solutions.

The societal benefits of a robust and resilient road network are numerous. First of all, when disruptive events occur, it helps to save lives because of its positive impact on road safety and the traffic flow of emergency services (ambulances, firefighters, etc.). Secondly, it saves public money due to lower repair costs and, finally, the increased availability of the roads means a lower impact on the local economy. To conclude, concrete roads provide resilient infrastructure, contributing to a resilient society.

SOME MORE INFORMATION

WHAT IS RESILIENCE

The IPCC (2014) defined resilience as the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation.'

Although any type of adverse event is considered, e.g. terrorist attacks, earthquakes etc., this fact sheet will focus on the negative effects of climate change.

THE EFFECTS OF CLIMATE CHANGE ON ROADS AND PAVEMENTS

The two main consequences of climate change that will affect roads are the increases in temperature and precipitation. Europe's road network is expected to undergo various stresses as a result: flooding, erosion of embankments and foundations, loss of road structure integrity and loss of pavement integrity.

2011-2020 was the warmest decade ever recorded, with global average temperatures reaching 1.1°C above pre-industrial levels in 2019. Human-induced global warming is presently increasing at a rate of 0.2°C per decade. [EEA]

An increase in the frequency and duration of extreme temperatures is also projected, mainly in the south of Europe. According to the European Environment Agency, this increase in hot days during the summer will lead to softening and rutting of asphalt pavements. Additionally, increased temperatures will intensify freeze-thaw cycles in the north of Europe, which could accelerate the deterioration of pavements and cause soil and slope instability and ground movement.

The number of large forest fires has also dramatically increased with serious impacts on environment and local communities but also on the pavements that are needed to give access to fire fighters. The projected increase in weather-driven fire danger in southern Europe is about 30-40% by the end of this century, compared with the period 1981-2010. [EEA]

Moreover, heavy rain in winter and summer for southern Europe over the period 2071-2100 is projected to increase by 25% compared to the present climate (1971-2000) based on a high emission scenario. The largest increases, up to 35%, are projected for central and eastern Europe [EEA]. The increased frequency of storm surges and flooding will affect pavement surfaces, granular subbases and subgrades of pavements if drainage systems have not taken this into account, leading to damage to pavements.

Another consequence of natural disasters (flooding, forest fires, etc.) is the necessary removal of debris [Oyediji et.al.], [Chen&Zhang], [Signore]. Unfortunately, trucks carrying debris are unavoidable in the event of severe damage after floods or wildfire events. This transport mostly occurs on roads which have not been designed for that kind of traffic. Researchers have observed a considerable increase in the IRI (International Roughness Index – measurement of unevenness) and a faster degradation for asphalt roads, in comparison with concrete roads. Rigid, concrete pavements are less impacted by overloading and provide the highest resilience to flood and wildfire damage.

PRECIPITATION - FLOODING

- Concrete roads are less susceptible to the swelling or shrinking of the subgrade compared to asphalt pavements. Therefore, concrete roads are the best solution in the event of cohesive soils such as clay.
- Delamination is no issue for concrete roads as they are built as a monolithic slab. This is also the case for two-layer concrete pavements.
- Among the different types of concrete roads, continuously reinforced concrete pavements (CRCP) are thought to be the most robust, especially in the case of flooding. The continuous reinforcement creates a bridging effect: it distributes the load over saturated bases and enables the pavement to cope with local subsidence. In Texas, several sections of

Road damaged after flooding, Gironde (France)
© Facebook page of Noaillan

Road damaged after floodwaters, Reading Drive, PA (USA)
© Rich Hawk / sauconsource.com

CRCP have been subjected to complete inundation every five years on average and to traffic loads four to five times the expected levels, while incurring minimal annual maintenance costs, thus proving the robustness and resilience of this pavement type. [Lukefahr]

- As well as concrete roads, hydraulically bound base layers are also robust solutions since they better withstand the effects of flooding compared to unbound granular layers. Indeed, cement bound granular mixtures, including lean concrete and roller compacted concrete, are known to be high quality, erosion- and frost-resistant solutions.

RESISTANCE TO EXTREME TEMPERATURES AND BUSHFIRES

Concrete pavements have proven to be durable and long-lasting in many different climatic conditions all over the world.

- All types of concrete roads (jointed plain, jointed reinforced, continuously reinforced and roller compacted concrete) are long-lasting and are designed and built to withstand changes in temperature or moisture.
- In some cases, special construction techniques are applied to ensure they work in extreme weather conditions.
- Thanks to well-designed joints and reinforcement, they are able to cope with large temperature variations.
- Concrete stiffness remains constant in the range of ambient temperatures without suffering softening or rutting. In fact, the surface of concrete is robust and keeps its properties over time regardless of climatic effects. This is true for most surface characteristics such as micro- and macrotexture, skid resistance and rolling noise production.
- Concrete is a fire-resistant material. This makes it the ideal material for pavements in areas where wildfires may occur.

Forest fires are a danger to citizens and emergency services
© Evan Collis, photographer of the Department of Fire and Emergency Services, Government of Western Australia

Heavily rutted asphalt pavement, due to heavy traffic and accelerated by high ambient temperatures © FEBELCEM

Due to climate change, the number of forest fires has significantly increased over the past years, in all parts of the world.

MITIGATION EFFECTS

Concrete roads and their surfaces can have several positive mitigation effects on climate change: slowing down global warming thanks to their high albedo, reducing CO_2 emissions by lowering the fuel consumption of heavy trucks, enabling recarbonation of recycled aggregates, reducing the risk of flooding with water pervious concrete pavements, and so on. For more information on all of these benefits, refer to EUPAVE's other available factsheets.

Parking lot in pervious concrete pavement, Dreux (France) © CIMbéton

WHAT POLICY IS NEEDED?

The societal benefits of a robust and resilient road network are numerous. First of all, when disruptive events occur, it helps save lives because of the positive impact on road safety and the traffic flow of emergency services (ambulances, firefighters, etc.). Secondly, it helps save money due to lower repair costs and, finally, the increased availability of the road means a lower impact on the local economy.

Choosing resilience means choosing a long-term approach for the procurement and construction of transport infrastructure in light of the consequences of climate change. An ideal solution is to build concrete roads, either as newly constructed pavements or as overlays on existing asphalt pavements (with thin or conventional thickness, bonded or unbonded). They offer not only a higher robustness and better performance but also a long serviceability with minimum maintenance, reduced life-cycle cost and a safe, durable and light-coloured surface.

.

More environmental benefits from concrete roads can be found on EUPAVE's infographic "Concrete Pavements Make Roads More Sustainable" (2019), https://www.eupave.eu/resources-files/infographic

References

Dealing with the effects of climate change on road pavements. (2012) PIARC Technical Committee D2 on Road Pavements, PIARC Technical Report 2012R06EN

EUPAVE (2016). A resilient road network for adaptation to climate change. Position paperv

Signore, J. (2020). The unseen impact of California wildfires on affected roadway pavements -

https://en.wikipedia.org/wiki/Climate_resilience

https://experience.arcgis.com/experience/5f6596de6c4445a58aec956532b9813d . European Environmental Agency [EEA]

Lukefahr, E. (2018) Continuously Reinforced Concrete Pavement Resiliency – A Case Study. Presentation at ACPA 55th Annual Meeting

Oyediji, O., Achebe, J., Tighe, S.L. (2019) Towards a flood-resilient pavement system in Canada – A rigid pavement design approach – TAC-ITS Canada Joint Conference, Halifax, NS

Willway, T., Baldachin, L., Reeves, S., Harding, M., McHale, M., Nunn, M. (2008). The effects of climate change on References highway pavements and how to minimise them: Technical Report. TRL, PPR 184

FACT SHEET
Long Service-Life
Low Life-Cycle Impact and Cost
Low Maintenance, less Disruption

Concrete roads are made with local raw materials, offer a long service life and are 100% recyclable

© InformationsZentrum Beton, Germany

Roads are essential for the transportation of goods and people and thus play an important role in a country's economic and social development.

Therefore, we need roads that allow a smooth traffic flow through a high level of availability. This in turn means that the number of construction sites for repairs, maintenance or reconstruction must be limited.

The choice of concrete pavements in road construction offers the advantages of "load-bearing capacity plus durability" both for pavements in a national or trunk road network and for local roads in a municipal road network. These advantages will become even more important on motorways given that an increase in traffic volumes is still predicted on these networks and guaranteed mobility and trouble-free freight traffic are necessary in an international and local economy.

Lifetimes of 30 to 40 years or more without structural damage are easily achieved with concrete pavements. Thanks to a long service life and low maintenance costs, the total life-cycle cost of concrete roads is low. The minimal number of road closures required for maintenance work entails less traffic disruption and thus offers significant ecological and economic benefits. A long, low-maintenance service life also means that the time until building materials are needed for new construction is extended. After demolition, the concrete is crushed and sieved and will be used again as recycled concrete aggregate in the construction of the new road, either in the sub-base or base layer, or to replace virgin aggregate in a new concrete mix. A long service life and recycling are both applications of circular construction; they conserve natural resources and reduce unavoidable emissions in producing building materials. Finally, thanks to modern construction techniques, concrete pavements allow a significant reduction in rolling noise emissions, rolling resistance and fuel consumption. In addition, they ensure a slip-free, non-deformable and bright surface, which is therefore safe for driving.

SOME MORE INFORMATION

ROAD AVAILABILITY

The term sustainability includes many different aspects, the significance of which varies with the circumstances. We expect roads to be as safe and comfortable as possible and ideally, free of congestion, allowing the movement of persons and goods at all times.
Traffic jams caused by road works or repairs have a negative impact on sustainability due to:

- traffic diversions, supported by current navigation technology, which often result in excessive traffic along alternative routes and consequently a structural overload on these routes;
- loss of valuable living, working and delivery time;
- excess fuel consumption and additional CO_2 emissions when stationary, in traffic jams and on detours;
- an increased number of accidents on construction sites and in the bypass area.

A sustainable traffic route should therefore be a free-flowing traffic route; a sustainable pavement should be durable and low maintenance.

LONG-LIFE PAVEMENTS AND THE RELATIONSHIP WITH SUSTAINABILITY

Service life is the period from construction until the end of a road's use. In technical terms, it is also referred to as the durability of a construction. To keep a road pavement in service, the two main construction methods, concrete and asphalt, require different maintenance efforts. During the design service life of concrete pavements – mostly 30 years – they require almost no scheduled maintenance, except for renewal of the joint sealing. (Other maintenance and preservation techniques are detailed further in the section on "Concrete pavement preservation"). In addition, in practice concrete pavements are usually used much longer, sometimes for more than 50 years for motorways and even reaching 100 years for low traffic volume roads. Thanks to the dimensioning methods and innovative materials and construction techniques available today, it is possible to create adapted designs to ensure lifetimes of up to 50 years or more. This is the special potential of the concrete construction method, which has not yet been fully implemented in the current road design rules.

The longevity of concrete pavements is beneficial when full life cycle analyses are made. This applies to both economic analysis (LCCA) and environmental impact studies (LCA). Such a holistic approach is the correct way to compare different alternatives (choice of pavement or renovation method, etc.) based on a long-term vision.

With comparable initial costs for roads in asphalt and concrete, but significantly lower maintenance costs for concrete, the whole life cost is always in favour of concrete.

In the concept of a "circular economy", longevity also plays a crucial role. Indeed, prevention is the preferred option in the waste hierarchy.

Prolonging the lifespan of a roadway by making the right design choices will be more resource efficient compared to frequent maintenance and rehabilitation or reconstruction.

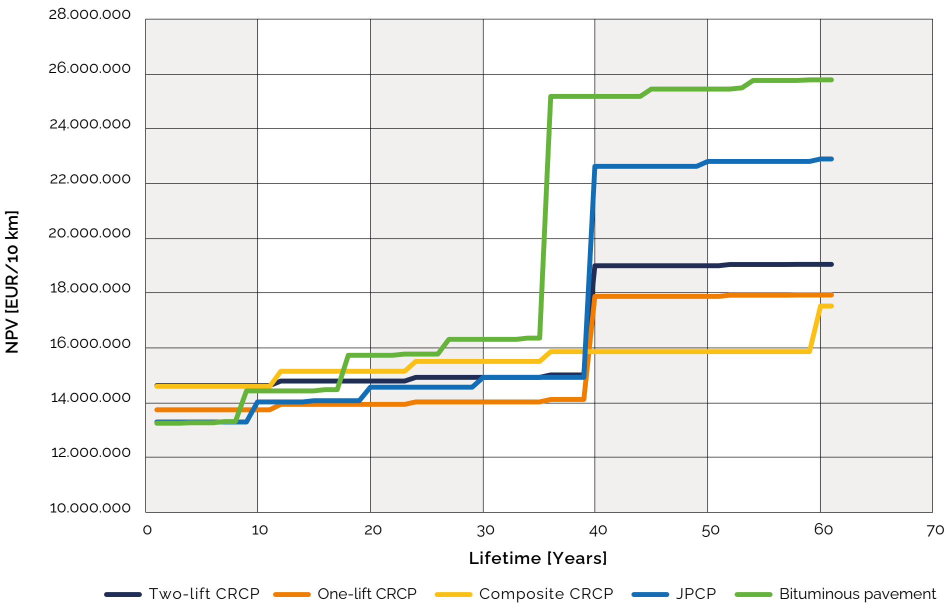
PPP (PUBLIC-PRIVATE PARTNERSHIP) PROJECTS

To illustrate this aspect of motorway construction, it is worth taking a look at some privately built highway sections in Germany from the last 15 years. Indeed, the basic contractual aspects of such projects, combining construction and operation, establish the most important economic sustainability criteria quite accurately:

- due to the contractual combination of construction and (30+ year) operation, the usual contractual warranty clause of two to five years is changed into direct responsibility for the quality for the entire duration of the operating contract.
- due to high contractual penalties for shutdown periods, the operator has a strong economic self-interest in ensuring maximum availability of the routes at all times.

Belgian motorway E40/A3, built as a 20 cm thick continuously reinforced concrete pavement: in service for 50 years

In addition, all motorway sections, built as PPP projects are provided within a shorter construction period and are built to a high standard of quality. The latter aspect is of particular economic importance, because at the end of the contractual operating time of mostly 30 years, these roads are not at the end of their service life but are still available to the public sector in a contractually-defined, good condition for use. The motorway can therefore be used immediately and without restrictions and have a high residual usage potential.



©AB-Roads

Comparison of the life-cycle cost (construction – maintenance – reconstruction) over an analysis period of 60 years for different motorway structures in concrete and asphalt.

CRCP = Continuously Reinforecd Concrete Pavement

JPCP = Jointed Plain Concrete Pavement

Urban road 50+ years old and still in good, serviceable condition

Due to these contractual requirements, almost all construction and operator consortia and the financiers behind them have chosen concrete pavements, as this meets the contractual requirements with a secure, long-term prognosis.

CONCRETE ROADS ALLOW EFFICIENT ASSET MANAGEMENT

Road investments are expensive, impacting public budgets and debts, and therefore need a long-term perspective. Concrete is a very predictable building material. If concrete road pavements are correctly designed, they are able to withstand traffic loads without changing their structural properties. The main criterion for adequate dimensioning is the thickness of the pavement: the thicker it is, the longer the design service life of the structure. For instance, an increase in slab thickness of only 2 cm provided for in the current design rules means an extension of the calculated predicted service life by 10 to 15 years.

Concrete construction offers the possibility of long-term technical and economical network management. With appropriate road monitoring, it is possible to forecast very precisely and plan in advance which sections need to be renewed at what time. Since concrete structures degrade very slowly, the time windows for renewal are relatively large, at 5 to 10 years. With appropriate knowledge of the structural capacity, the maintenance of a network can be planned over the long term and also offers time reserves. This allows far-sighted determination of demand and planning of the use of financial resources. An intelligent rehabilitation management also takes into account maintaining sufficient network availability in the event of construction activity.

CONCRETE PAVEMENT PRESERVATION (CPP)

The FHWA (U.S. Federal Highway Administration) report "Strategies for Concrete Pavement Preservation" (Van Dam et al.) introduces a new and broader definition of CPP: "*a strategy of extending concrete pavement service life as long as possible by arresting, greatly diminishing or avoiding the pavement deterioration process*".

There are three ways to achieve this strategy:

1. **Designing and constructing durable long-life concrete pavements.** This means they are structurally adequate and relatively distress-free throughout a long service life. Key factors for this are structural design, durable materials, and appropriate construction techniques.

2. **Overlays (asphalt or concrete) as a preservation treatment.** In this case, the existing road structure serves as a base for the new pavement, which allows a reduction in the need for new materials, their transportation, associated emissions and construction time and cost. Materials savings come from reduced design thickness and the absence of a new base layer. Concrete overlays over existing concrete roads, with an interlayer of geotextile or asphalt, have proven to be very durable and cost-effective solutions. On existing CRCP (continuously reinforced concrete pavement), an asphalt wearing course is also an option. Although it needs periodical replacement, it provides a comfortable surface while the underlying concrete keeps on fulfilling the structural function.

3. **Maintaining the serviceability of the existing concrete pavement using CPR (restoration) treatments.** Preventive maintenance and minor rehabilitation activities consist mainly of joint renewal and partial and full-depth repairs. However, several other techniques are available to repair structural or surface distresses. For example, dowel bar retrofit (DBR) is the placement of dowels across joints or cracks in an existing concrete pavement to restore


Grinding machine in operation and a finished very low-noise "Next Generation Concrete Surface"

load transfer and solve the problem of moving transverse joints and associated noise and vibrations. And old noisy and bumpy surfaces can be turned into silent, smooth roads thanks to grinding and grooving, the so-called 'Next Generation Concrete Surface'.

It is clear that CPP is perfectly in line with the concept of long-life concrete roads.

OTHER BENEFITS OF CONCRETE PAVEMENTS

In our previous fact sheets, you can find more information on:

- Cool, light reflecting surfaces: https://www.eupave.eu/resources/how-high-albedo-contributes-to-reduction-of-carbon-emissions-from-road-transport/
- Less fuel consumption: https://www.eupave.eu/resources/fact-sheet-less-fuel-consumption/
- 100% recycling: https://www.eupave.eu/resources/fact-sheet-100-recycling/
- Climate resilience: https://www.eupave.eu/resources/fact-sheet-climate-resilience/

More environmental benefits from concrete roads can be found on EUPAVE's infographic "Concrete Pavements Make Roads More Sustainable" (2019), https://www.eupave.eu/resources-files/infographic

References

BEELDENS A. (2022) Life-cycle cost of CRCP – a comparative study.

DIEPENDAELE, M. (2018). A guide on the basic principles of Life-Cycle Cost Analysis (LCCA) of pavements. EUPAVE.

PECK, M. (2020). Betonstraßen sicher und dauerhaft. InformationsZentrum Beton GmbH & Gütegemeinschaft Verkehrsflächen aus Beton e.V.

VAN DAM, T., SMITH, K., SNYDER, M., RAM, P., DUFALLA, N. (2019) Strategies for Concrete Pavement Preservation. Interim Report FHWA-HIF-18-025 prepared for Federal Highway Administration, Washington, DC 20590, U.S.

FACT SHEET
Sustainable Water Management

Concrete contributes to more ecological water cycle management

© Ebema

Water is a scarce resource that we must handle with care, in an integrated manner throughout the water chain. This is even truer now that climate change is leading to wetter winters, drier summers and more extreme weather phenomena. Only through an integrated approach to water management can we win this challenge.

In addition to heat waves, floods and forest fires, climate change is also causing increasingly long periods of drought. During such periods, water shortages may occur, not only because of a lack of precipitation but also because of insufficient water reserves in the subsoil due to falling groundwater levels. This, in turn, has to do, among other things, with the large proportion of paved and built-up areas in our living environment. This problem is exacerbated by demographic developments: the increase in the world's population and its concentration in large cities.

What can we do in practice? First of all, it is important to be aware of the amount of water consumed and, in some cases, wasted. Responsible water use is the start of good water management.

There are many possible solutions for maintaining the water balance, such as:

- infiltration pits or ditches;
- rainwater tanks and larger rainwater harvesting basins to capture and store water in wet periods;
- green roofs, with vegetation, which limit the run-off of rainwater;
- water-permeable pavements, which can store the water in the road structure and provide deferred evacuation or allow it to infiltrate into the subsoil.

Many of these solutions can be made in concrete. After all, concrete is extremely suitable for water purification facilities and for the storage and distribution of drinking water, rainwater and wastewater. And concrete certainly occupies a prominent place in water-permeable road surfacing, for which the general principle is to collect rainwater as close as possible to where it falls and, if possible, to allow it to infiltrate into the subsoil.

PERVIOUS CONCRETE PAVEMENTS

Various solutions are available for water-permeable concrete pavements, both with in-situ cast draining concrete and with pre-cast concrete products. The area of application of pervious pavements is roads with low traffic volume, car parks, bicycle and walking paths and squares. The design of these pavement structures must take into account the bearing capacity to support traffic loads together with surface water management, i.e. infiltration and sufficient storage. The draining character of these pavements can also be easily combined with a decorative aspect through special shapes and colours.

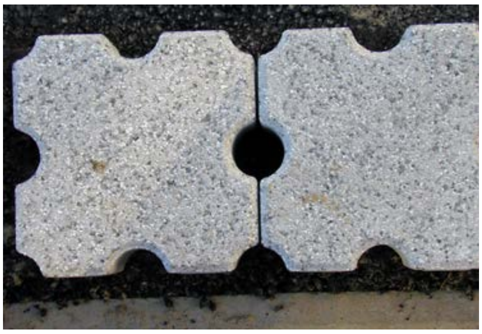
The benefits of permeable pavements in urban environments – sometimes referred to as a 'sponge city' – are:

- flood prevention;
- a cooling effect, thus reducing the "urban heat island effect" and providing better thermal comfort in the environment and the buildings;
- a financial gain due to the redundancy of a sewage system;
- beautifying the surroundings with aesthetic paving.

PERMEABLE SOLUTIONS IN PRECAST CONCRETE ("CONCRETE BLOCK PERMEABLE PAVING")

Generally, permeable/pervious precast concrete paving blocks can be categorised in four different types:

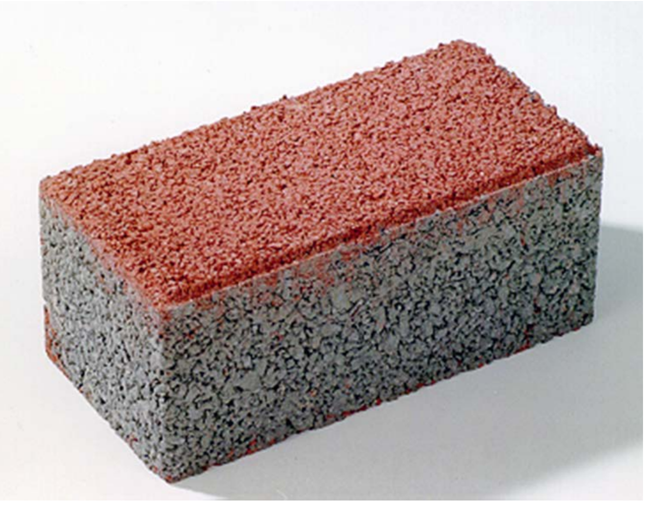
- **impervious concrete paving blocks with widened joints**, which are created by spacers at the sides of the blocks. The *joint surface/total surface* ratio needs to be sufficient to evacuate the run-off water and may be specified in the technical specifications in some countries, e.g. a minimum of 10%. Obviously, the joint filling material must be water permeable.
- **impervious concrete paving blocks with drainage openings**. Due to their specific design, these concrete pavers are designed to allow water to infiltrate through the openings created after laying. For this type of stone, it is in fact sufficient to save an opening on one or more sides or centrally in the stone. In this case, too, the proportion of openings determines the pavement's drainage capacity.



© FEBE

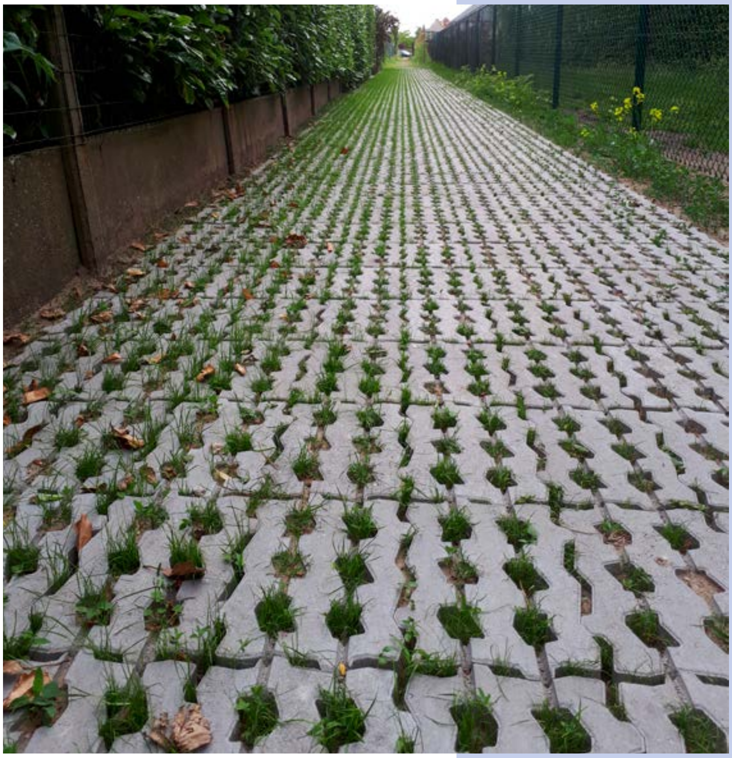
© FEBE

© FEBE



- **porous concrete paving blocks**. In this case, the typical dense concrete mix is replaced with a porous one. The water can percolate through the open-graded structure. In this case, the water permeability of the paver itself is prescribed and tested.
- **grass concrete tiles**: in this type of paving block the openings can be filled either with grass or with a permeable fine aggregate. Today, the old types have been complemented by new, modern and decorative designs with customised sizes, shapes and colours.

© Stradus



© FEBE

Decorative draining concrete for public spaces © Holcim

Car park with a pervious concrete pavement, Dreux (France) © CIMbéton

PERVIOUS SOLUTIONS IN IN-SITU CAST CONCRETE

- **in-situ cast porous concrete**. This is a pervious type of concrete thanks to its open structure, due to the absence of sand in the concrete mixture. The coarse aggregates are glued to each other by the cement paste. The percentage of connected voids in the concrete will determine the water permeability but also the concrete's strength. Indeed, this type of concrete is characterised by a lower strength compared to conventional concrete. Therefore, the field of application is limited to pavements with no or limited heavy traffic.

A special application, developed in the Netherlands, is called "Bermcrete". It consists of slipforming longitudinal strips in porous concrete along the edges of rural roads in order to widen them and make them safer.

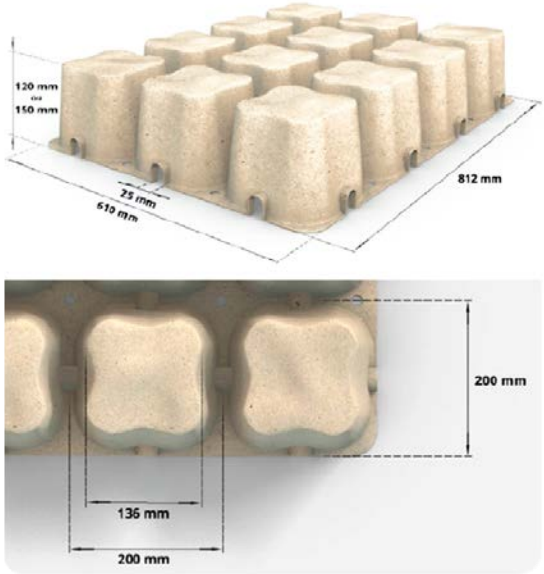
Construction of 'Bermcrete' in the Netherlands © Heijmans

- **in-situ cast cellular reinforced concrete:** this monolithic system, based upon a proprietary design, is obtained with biodegradable formwork surrounded by cast-in-place concrete to form pervious alveolar slabs filled with grass or aggregates. A conventional concrete mix is used, making higher strengths

Applications of cellular reinforced concrete for a parking lot and a tramway © Viaverde

possible. This solution, like most of the other permeable pavements, is mainly used for car parks but also for tramway platforms, walking paths, private access, etc.

It is important to deal with rainwater properly, both in public spaces and on private properties. First, it should be collected and used if possible. Secondly, it should infiltrate the soil. When pavements are needed, permeable solutions must be considered. Concrete offers a wide range of water-permeable pavements, both in-situ cast and with precast concrete paving blocks. In this way, the sewage system is relieved, the soil can absorb new water reserves and the risk of flooding is reduced.



Biodegradable formwork © Viaverde

More environmental benefits from concrete roads can be found on EUPAVE's infographic "Concrete Pavements Make Roads More Sustainable" (2019), https://www.eupave.eu/resources-files/infographic

References

Interpave. (2020). Understanding permeable paving & suds. www.paving.org.uk , Leicester, U.K.

Ployaert, C. (2006). Beton en waterbeheer (Concrete and water management). FEBELCEM, Brussels, Belgium.

www.viaverde.fr

Published by: EUPAVE
European Concrete Paving Association
Avenue des Arts 20
1000 Brussels

T +32 (0)485 78 03 91
info@eupave.eu
www.eupave.eu

September 2023