Statens vegvesen

Notat

Til:	Marit Due	**Saksbehandler:**	Rabbira Saba
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Deltakelse på konferansen TRA2024 i Dublin, Irland

Bakgrunn

Sara Anastasio, Brynhild Snilsberg og Rabbira Garba Saba søkte om og fikk NVF Stipend i 2023 for å få dekket utgifter tilknyttet deltakelse på TRA-konferansen som ble avholdt i Dublin i april 2024. Målet med dette var å presentere og publisere en del av forsknings- og utviklingsarbeidet som gjøres på teknologiavdelingen i DoV, samt å treffe, knytte kontakter og bygge nettverk med fagpersoner fra andre land innen fagområdet vegteknologi. Vi benyttet stipendiet og deltok på TRA2024-konferansen, der vi holdt to presentasjoner. Dette notatet gir en kortfattet beskrivelse av de to artiklene (papers) fra gruppen som ble presentert på konferansen, samt det faglige utbyttet vi fikk og våre opplevelser av konferansen.

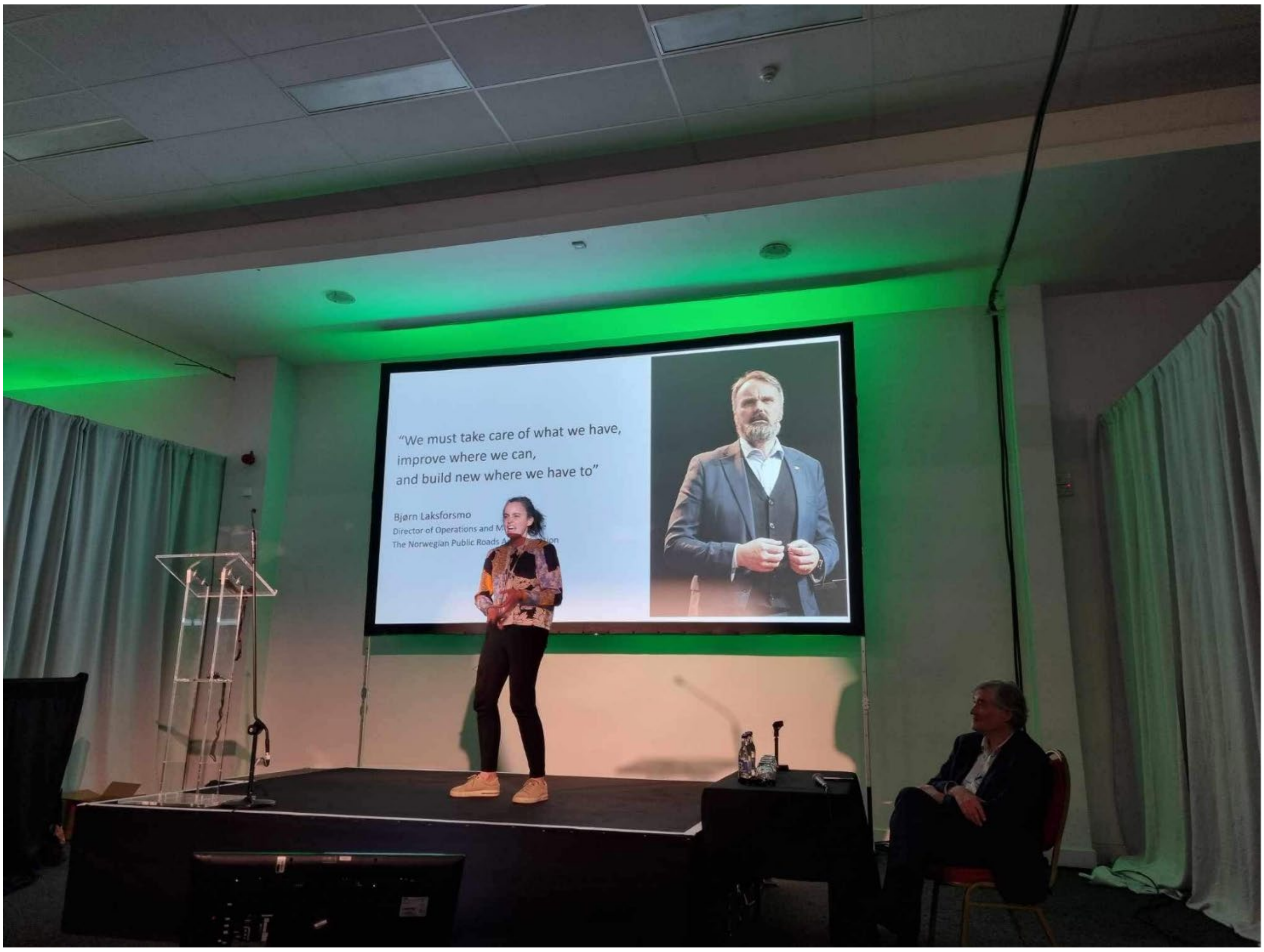
Papers

Som nevnt ovenfor ble to papers (Paper 1 og Paper 2) presentert på konferansen. Paperene er vedlagt dette notatet. Paper 1, som ble presentert av Brynhild Snilsberg på konferansen, handler om arbeid som er gjort i VegDim-programmet. VegDim er et FoUI-program som har som mål å utvikle og ta i bruk et digitalt mekanistisk-empirisk dimensjoneringssystem for vegoverbygninger i Norge. Programmet ble satt i gang i 2018 og skal avsluttes i år. I VegDim-programmet har man valgt å videreutvikle, tilpasse til norske forhold og ta i bruk et dimensjoneringssystem som heter ERAPave PP, utviklet av VTI (Veg- og transportforskningsinstituttet) i Sverige. Paper 1 beskriver arbeid som er gjort i Norge for å videreutvikle, tilpasse til norske forhold, kalibrere og implementere ERAPave PP. Følgende temaer er beskrevet i Paper 1:

- Evaluering av aktuelle ME systemer og valg av ERAPave PP
- Utvikling av frostdimensjoneringsmodell for vegoverbygninger
- Etablering av materialdatabase for norske vegbyggingsmaterialer
- Etablering av et system for innhenting av klimadata fra relevante værstasjoner og valg av temperatur modell
- Pågående arbeid om bruk av WIM (Weigh-in-Motion) data for å ta hensyn til trafikkbelastning ved dimensjonering av vegoverbygninger
- Utvikling av en web-basert løsning for å tilgjengeliggjøre og implementere programmet, og implementering av systemet i N200
- Kalibrering til norske forhold

Hoveddelen av Paper 2, som ble presentert av Sara Anastasio, handler om arbeid som gjøres i FoUI programmet Asfaltdekkers funksjonsegenskaper som pågår i regi av teknologiavdelingen, divisjon DoV. Målet med dette programmet er å utvikle metoder og teknologi som bidrar til å redusere asfaltens miljøavtrykk samt forbedrer bestandigheten av asfaltdekker (øke levetider). Paper 2 beskriver den norske tilnærmingen til dimensjonering, bygging, og vedlikehold av asfaltdekker med fokus på reduksjon av CO_2 -utslipp fra asfaltlegging. Følgende temaer er beskrevet i Paper 2:

- Vektlegging av CO2 reduksjon i asfaltkontrakter
- Bruk av ERAPave PP (som er omtalt i Paper 1) til å beregne asfaltdekkets levetid for så å bruke levetiden i livsløpsanalyser (LCA) for å beregne dekkets miljøavtrykk.
- Utfordringer og fremtidige planer



Faglige utbytte

TRA konferansen dekker vidt forskjellige temaer fra overordnet transportpolitikk til mer faglige og tekniske temaer tilknyttet transportinfrastrukturene for de ulike transportformer inklusiv veg-, bane-, sjø- og lufttransport. Konferansen er en

arena der transportmyndigheter, leverandører, entreprenører, transportmiddelprodusenter og forskningsinstitusjoner får mulighet til å vise frem og presentere sine arbeider, produkter, og tjenester.
Temaer som klima og miljø, bærekraft, avkarbonisering, bruk av stordata, KI og automatisert transport har vært gjengangere på de forskjellige sesjonene og ser ut til å engasjere fagfolk fra ulike fagområder. Disse temaene er av interesse for oss vegteknologer og relevant for fagområdet vårt. Ved deltakelse på flere sesjoner (både poster og plenary) der disse temaene ble tatt opp og diskutert fikk vi nyttig informasjon om utviklingen i ulike land tilknyttet disse temaene. Når det gjelder tekniske sesjoner som angår vegteknologi fagområdet svarte derimot ikke konferansen til forventningene. Dette skyldes at de aller fleste av disse sesjonene gikk parallelt på en av dagene som gjorde det vanskelig å følge. I tillegg opplevde vi at i noen av sesjonene er det litt dårlig sortering av presentasjoner/temaer, dvs. sesjonene hadde presentasjoner fra ulike temaer som, strengt tatt, ikke er beslektede.

Nettverksbygging

En av fordelene med deltakelse på internasjonale konferanser er nettverksbygging. På TRA konferansen har vi fått mulighet til å diskutere faglige saker med fagfolk (noen kjente fra før, men en del nye fagpersoner) fra ulike land, dvs. deltakelse på konferansen har gitt oss muligheten til å styrke det faglig nettverket vårt. Dette vil være nyttig i det daglige arbeidet vi gjør.
I denne sammenhengen vil vi nevne at Konnekt arrangerte en hyggelig middag for norske deltakere på konferansen der folk fra NTNU, SVV, ITS Norge, Q-Free, Kartverket, OsloMet, SINTEF, og Konnekt deltok. Dette ga en mulighet for fagfolk fra ulike norske organisasjoner til å treffes og knytte kontakter.

Andre opplevelser

I løpet av vårt opphold i Irland har vi reist rundt i Dublin og tok en dagstur til Nord-Irland (Storbritannia). På disse turene har vi fått mulighet til å se hvordan veiene er utformet i Irland, hvilke type asfaltmaterialer det brukes og en del trafikksikkerhetstiltak som er i bruk langs veiene. Når det gjelder klima, topografi og trafikkforhold er det større forskjeller mellom Norge og Irland. Likevel synes vi at det er nyttig å se hvordan andre land løser utfordringene tilknyttet veginfrastrukturen.

Vedlegg: Paper 1

Further development and implementation of a mechanistic-empirical design and analysis system for pavement structures in Norway

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Abstract. Design of pavement structures has a great impact on life cycle cost (LCC) and environmental effect of pavements. At present pavement structures in Norway are designed with use of empirical based tables and requirements described in the Norwegian design guideline for pavement structures. The current design procedure does not allow prediction of performance and evaluation of the effect of changes in material, climate, and traffic, which makes it difficult to accurately calculate the LCC and environmental impact. Mechanistic-empirical (ME) systems can overcome these shortcomings since they allow prediction of performance based on realistic material, climate, and traffic data. Therefore, a research and development program was initiated by the Norwegian Public Roads Administration (NPRA) to further develop and implement a ME design and analysis system for Norwegian conditions.

The work involved evaluation of existing ME systems around the world to find a system that can be adapted to Norwegian conditions. Based on this evaluation a system called ERAPave PP (Elastic Response Analysis of Pavements –Performance Predictions) which was under development by The Swedish National Road and Transport Research Institute (VTI) in collaboration with the Swedish Transport Administration (STA) was selected. NPRA and STA established a cooperation program to further develop and implement the ERAPave PP in Norway and Sweden. The objectives of the project were to further develop ERAPave PP by adding models for climate and frost heave, as well as to establish databases for implementation of the system in each country.

This paper describes the process with selection, further development, calibration, and implementation of ERAPave PP for Norwegian conditions.

Keywords: ME-design, Analysis; Performance prediction; Calibration; Implementation.

Introduction

Pavements represent a significant part of the road infrastructure asset, and the design of the pavement structure has a great impact on life cycle costs (LCC) and environmental impact for pavement structures. Traditionally, pavements have been designed using empirical methods. Such methods do not allow prediction of performance and evaluation of the effects of changes in material, climate, and traffic, which makes it difficult to accurately calculate the service life, and hence the LCC and environmental impact in terms of life cycle assessment (LCA).

Since the advent of Burmister's elastic multilayer theory, efforts have been made by many researchers in various countries to develop rational methods for design of pavement structures and overcome the limitations of the empirical methods. These methods are based on the calculation of stresses and strains in the pavement structure under wheel loading using mechanistic methods and prediction of performance using empirical equations, for which the calculated stresses and strains will be input parameters. Such methods are called mechanistic-empirical (ME) pavement design methods and are being utilized in many countries.

Most of the existing ME pavement design methods use elastic layer theory to calculate stresses and strains under wheel loading. However, these existing systems vary in their approach to performance prediction and in how they use the predicted performance to carry out the design. Based on their approach to performance prediction, the existing ME design systems can be grouped into two: those that directly predict performance in the form of distress development (such as rut depth and cracking) over the design period and those that predict the allowable number of load repetitions based on predefined failure criteria.

This paper describes the selection, further development, calibration and implementation of a ME system called ERAPave PP (Elastic Response Analysis of Pavements –Performance Predictions) to Norwegian conditions.

The need for ME design and analysis systems

At present, pavement structures in Norway are designed with use of a purely empirical method using index values and load distribution coefficients. The design requirements are described in the design guideline for pavement structures [1]. This method was developed in the 1960ies and has been adjusted and improved several times since based on experience and new knowledge. The goal of the design method is to obtain a technically and economically optimal pavement structure both for new construction and maintenance. The current design procedure is easy to use and conservative to take care of uncertainties involved in planning and construction of the road. However, the method has several shortcomings: it does not allow prediction of performance and evaluation of the effect of changes in material, climate, and traffic, difficult to adapt to local conditions, manual design (not digitalized), and requires experience in pavement engineering. Since it does not allow performance prediction, i.e. calculation of service life, it is difficult to accurately calculate LCC and environmental impact (LCA) for pavement structures. ME systems can overcome these shortcomings since they allow prediction of performance based on realistic material, climate, and traffic data. This will provide larger flexibility and the possibility to optimize the pavement design based on LCCA and LCA, and digital documentation of the design and future need for maintenance.

Selection of system

Several countries have or are in the process of developing and implementing ME systems. The existing ME systems are developed and calibrated to certain conditions (materials, building methods, climate, and traffic) for a specific country or area. These systems must be adjusted and calibrated if used elsewhere and can therefore not directly be implemented in Norway. An evaluation of different systems was conducted to find the best system that can easily be adapted to Norwegian conditions as described in [2]. The selection criteria were focused on the following questions:

1. Does the system predict pavement performance?
2. Are the pavement performance models relevant to Norwegian conditions?
3. Does the system have flexibility for further development?
4. Does the system have a frost model to calculate frost penetration and frost heave, or is it possible to include this?
5. Does the system allow the use of axel load spectrum as traffic input?
6. Does the system have a climate model?
7. Can the system be calibrated and adjusted to other conditions?
8. How can the system be acquired/procured?

According to these criteria, the Swedish system called ERAPave PP was chosen since it was the best fit for our needs: it predicts pavement performance, the performance models are relevant to the most important Norwegian deterioration mechanisms, and it can be used both as a design and analysis system for pavement structures. ERAPave PP is under development by the Swedish National Road and Transport Research Institute (VTI) which makes it easy to further develop and adapt to Norwegian conditions. The conditions in Sweden and Norway are comparable regarding traffic, climate, and building materials & methods, which provides the basis for cooperation between the road administrations in both countries in further development of ERAPave PP. Consequently, a cooperation program was established between the Swedish Transport Administration (STA) and the Norwegian Public Roads Administration (NPRA).

Further development and calibration of ERAPave PP to Norwegian conditions

ERAPave PP is a ME pavement design and analysis system. It uses elastic multilayer theory to calculate response, i.e., stresses and strains. The calculated stresses and strains are used in the performance prediction models to predict the development of rutting in the various layers and fatigue cracking in the bound layers. ERAPave PP has also in-built performance model for prediction of rutting caused by studded tire wear. A new model for calculation of frost heave and a climate model for calculation of temperature have been developed in this project. A more detailed description of ERAPave PP is given in [3, 4]. In the following sections, work done in Norway to adapt and calibrate ERAPave PP to Norwegian conditions is described.

Establishment of input databases to facilitate implementation

The input data to ERAPave PP include material, traffic, and climate data. To facilitate the implementation and use of ERAPave PP in Norway, databases of the basic data required are established and connected to ERAPave PP.

Material data

Elastic moduli and Poisson's ratios for materials in the layers of the pavement structure are the most important material property data required by ERAPave PP. In addition, wear resistance property of the aggregate in the surfacing layer and frost properties of subgrade materials are required. An extensive laboratory testing of the commonly used asphalt mixtures in Norway was conducted at the Norwegian University of Science and Technology (NTNU) to establish dynamic modulus master curves for the various mixture types. The dynamic modulus master curves were established using the sigmoidal model described in equation 1.

$$\log(|E^*|) = \delta + \frac{\alpha}{1+e^{\beta-\gamma\log(f)}} \quad (1)$$

Where |E*| is the dynamic modulus, f is the frequency, δ and δ + α are the dynamic moduli at the infinitesimal and infinite frequencies, respectively, and β and γ are the model parameters. The William, Lindel and Ferry (WLF) equation (eq. 2) is used to shift measured values at a reference temperature of 15°C.

$$\log\big(\alpha(T)\big) = \frac{-C_1(T-T_r)}{C_2+(T-T_r)} \quad (2)$$

Where α(T) is the shift factor, T is the testing temperature, T_r is the reference temperature and C_1 and C_2 are the model parameters. A more detailed description of the work done to establish dynamic modulus master curves for Norwegian asphalt mixtures are given in [5].

The stiffness moduli for coarse crushed rock materials used in base, subbase and frost protection layers are estimated using back-calculation from deflection measurements conducted on some test sections. Laboratory testing is underway to determine the stiffness modulus of fine-grained subgrade materials (clay and silt). For unbound granular materials the stiffness modulus at the optimum moisture content is adjusted for the effect of varying moisture content using the model shown in equation 3.

$$\log\frac{M}{M_{opt}} = a + \frac{b-a}{1+e^{\left(\ln\frac{-b}{a}+k_m\left(S-S_{opt}\right)\right)}} \quad (3)$$

Where M is stiffness modulus at degree of saturation S, M_{opt} is the stiffness modulus at the optimum degree of saturation S_{opt}, and a, b, k_m are model parameters.

A material database, which contains the required material properties, is built in ERAPave PP and when a user chooses a material the program automatically picks the required properties from the database.

Climate data

It is well known that temperature and moisture content in the pavement structure have significant effect on performance of pavements. Temperature affects deformation in asphalt layers as well as low temperature cracking and frost heave during winter. Moisture content affects the stiffness of unbound layers specially during the spring thaw period. ERAPave PP uses a temperature model to calculate temperature at different depths within the pavement structure. The temperature model is based on the finite-volume method and is described in detail in [6]. The temperature model uses data for air temperature, wind speed, and solar radiation as input data and calculates temperature at required depths in the pavement structure. The calculated temperatures are used in conjunction with dynamic modulus master curve for asphalt materials to calculate stresses and strains, and the development of deformation rutting in the asphalt layers. To obtain the input data for the temperature model (air temperature, wind speed and solar radiation), ERAPave PP uses a map-based solution, which allows the user to choose the project location or specify the project coordinates. The program then picks the required data from the nearest weather station for a specified period of time. In ERAPave PP frost heave is calculated using the SSR-model (Seppo Saarelainen Routanousu) [7], using data for frost index and frost properties of materials for the project location.

Traffic data

ERAPave PP allows two ways of inputting data for traffic loading. The first approach is to use AADTT (average annual daily truck traffic) and convert it to number of equivalent single axle loads. The second approach is to use traffic load spectra, i.e., axle load distribution data from weigh-in-motion (WIM) or Bridge-WIM measurements. In Norway, there is currently lack of data on axle load distribution. However, there is an ongoing work to install and use WIM measurements as part of implementation of ERAPave PP. The aim is to establish a traffic loading database and connect it to ERAPave PP for use in design and analysis of pavements.

Calibration of ERAPave PP to Norwegian conditions

As mentioned earlier in this paper ERAPave PP contains empirical models that are used for prediction of performance over the design period. The performance prediction models that are currently implemented in ERAPave PP include rutting models for bound and unbound layers, fatigue cracking model for bound layers, studded tire wear model for surfacing layer and a frost heave model. These empirical models need to be calibrated to Norwegian conditions using measured performance data such as field measured rutting data.

Several reference road sections were selected for the purpose of calibration of the performance models and an extensive work to gather data for these sections is ongoing. The data being collected include the original construction data (layer thicknesses, material types) and deflection measurements, which are being used to back-calculate stiffness modulus for the unbound layers. Core samples were taken from the asphalt layers and tested in the laboratory to determine the dynamic modulus master curve.

In Norway pavement condition data (rutting, roughness, etc.) is measured every year on major roads. The condition data is stored in a road data bank. The data collected for the refence sections will be used in conjunction with the condition data from the road data bank to calibrate the performance models.

Implementation of ERAPave PP in Norway

There is ongoing work to implement the new system in the Norwegian pavement design guideline. The implementation process includes development of a Norwegian web-application and setting of design requirements in the guideline. In addition a training program is being developed to train potential users, both in the road administrations and in consulting companies.

Summary and conclusions

A work being conducted to select, adapt and implement a ME pavement design and analysis system in Norway is described in this paper. The work includes establishment of input databases for materials, climate, and traffic, as well as calibration of ERAPave PP to local conditions. The adaption of ERAPave PP will give greater flexibility in the choice of both materials and layer thicknesses compared to today's practice. The transition to a ME design system will allow consideration of local conditions (locally available materials, climate) and provide a better understanding of the pavement deterioration mechanisms. We believe that the new system will contribute to improved planning and management of the road network because it enables prediction of the service life of pavement structures. It could also lead to lower environmental impact in terms of energy and GHG reduction in construction and maintenance of roads. Performance prediction will also enable documentation of consequences of different choices (standard materials, quality, layer thickness, change in traffic etc.).

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Vedlegg: Paper 2

The Norwegian Approach to Future Design, Construction, Maintenance, and Rehabilitation of Asphalt Pavements

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Abstract. Many actions are being undertaken by Norwegian road owners to reduce the environmental impact of construction and maintenance of pavements. Thanks to the collaboration with the local contractors association, a new procurement system, based not only on the financial cost of maintenance operations but also on CO_{2eq} emission, has been introduced. In three years, it has already led to a 30% reduction of CO_{2eq} emissions in maintenance projects. In addition, an analytical pavement design and analysis system, built to consider the local conditions (available materials, traffic loads, climate), will soon juxtaposed to today's guidelines based on empirical methods. It will facilitate not only the use of customized solutions but also the prediction of the pavement service life.

Through the introduction of more flexible and performance-oriented procurement and design systems, the aim is to increase the consultants and contractors' freedom in choosing the right solution, as far as the environmental and economic impact are balanced with the expected service life; the final purpose being encouraging the technological advancement needed to achieve the common climatic goals. This paper intents therefore to evaluate the progress and consequences of the Norwegian pavement sector's strategy for a more sustainable infrastructure.

Keywords: Pavement design; Procurement; Service life; CO_{2eq}.

1 Introduction

"*We must take care of what we have, improve where we can, and build new where we have to*" expresses the vision of the Norwegian Public Road Administration (NPRA) of contributing to the transition into a low-emission society [1]. It intuitively summarizes the progressive societal shift in the western countries from a consumerist prospective of resources abundance and constant growth, to a future premised on sufficiency and resiliency [2]. Encouraged by the international acknowledgment of the ongoing climatic change and the ambitious greenhouse gas emissions goals, it extends to any aspect of the country's society and economy, including the asphalt pavement sector.

After years of relatively limited and slowly implemented advancements, the emphasis on the reduction of greenhouse gas emissions has been the kickstart the pavement industry needed to begin a small revolution leading to the flourishing of new technologies, materials and routines.

In Norway, the introduction of new technologies and materials was initially led by the larger asphalt companies and industry's associations, thanks to the possibility to focus on R&D and the availability of resources to implement internal changes. While their motivation might swing between improving EHS (environment, health and safety) and the strictly financial gains, the repercussions spread to the whole asphalt industry and led to a National Transport Plan encouraging technological advances and daring to think differently [3].

On the road owner side, the need to keep abreast with the industry and to contribute to the national emission target for 2030 triggered drastic changes in how pavements are designed, built, maintained, and rehabilitated. New tendering processes have been introduced both at national, county and municipality level, and a new design method is being developed to increase the contractors' and consultants' freedom in the choice of materials; to stimulate the use of low emission technologies and to overall increase the service life of pavements.

This paper will give an overview of how the Norwegian road owners (NPRA, counties and municipalities) are striving to reduce the environmental footprint of their infrastructure and develop a future-oriented pavement sector.

2 Procurement process

Starting from 2018, the NPRA, together with other road owners and the Norwegian Contractors Association (Entreprenørforeningen - Bygg og Anlegg), has gradually introduced the use of Environmental Product Declarations (EPD) in pavement maintenance contracts. In just four years, the NPRA went from requiring delivering any available EPD to use CO_{2eq} weighting in almost 90 % (24 of 27) of its contracts. Four of these using a combination of CO_{2eq} weighting and life-cycle costs. The implementation process, a detailed description of the framework for EPDs and how an EPD-calculator has been developed specifically for the paving industry can be found in [4].

The scope behind the introduction of the new tendering process, is to both reduce the emissions linked to pavement maintenance contracts and, at the same time, encourage the development and purchase of low emission technologies, materials and giving more freedom to the industry. The aim is to reduce the amount of emission linked to maintenance contracts by 65% compared to 2020 within 2030.

2.1 CO2eq weighting and life cycle costs

When presenting a bid for a paving contract, each bidder is required to attach an EPD, describing the product's environmental performance, to the monetary price. The values corresponding to the stages A1 to A5 (product and construction stages) are then used to determine the environmental cost of the product in terms of CO_{2eq}.

In tendering process, the bidder with the lowest CO2eq cost establishes a baseline. All other bidders, with higher emissions, will have a certain among NOK/kgCO_{2eq} added to the monetary price. Depending on the road owner, this amount varies between 5 and 20 NOK (≈ 0,5 to 2 €/kgCO_{2eq}). The adjusted bidding sum (original price plus price based on the emissions) will determine the winning contractor. At the end of the contract, the actual CO_{2eq} cost will be documented by the winning bidder.

In the following Table 1 are shown the results collected between 2020 and 2023 by three road owners: the NPRA that manages the national roads and two counties, Troendelag and Viken, that manage the county roads in the proximity of Trondheim and Oslo. The 2020 values correspond to a traditional tendering process based on the lowest price, while the following years saw the introduction of CO_{2eq} weighing in more and more processes. The results are therefore to be considered as an average value from both types of contracts for the years 2021 to 2023. The introduction of CO_{2eq} weighing in 2021 has led to a clear impact for the NPRA contracts with a consistent decrease of emission, 30% in three years, in accordance with increasing amounts of tendering processes based on the new criteria. The same conclusion cannot yet be drawn for the county roads. However, it is clear from the EPDs that the contractors are taking several initiatives to reduce their footprint. So far, particular focus has been put into the use of bio additives and recycled asphalt (to reduce the emission quota of the bituminous products), low temperature mixes, and in the use of more environmentally friendly energy sources such as wood chips.

Table 1. Amount of kgCO_{2eq}/tonn asphalt between 2020 and 2023 as provided by the contractors in the EPDs (A1 to A5); the measured values (a) and including the end-of-life stages, C1 to C4 (b). The data are provided by the NPRA and counties of Troendelag and Viken.

	2020	2021	2022	2023
NPRA	62	54	48	41 (49)[b]
Troendelag County	69	75	53	-
Viken County	-	32 (31)[a]	27 (31)[a]	-

2.2 Challenges and future plans

One of the main difficulties to evaluate the effect on the new tendering processes is in the data collection. This is due to the large amount of road owners in the country and municipal level and the internal communication challenges. The lack of data makes it difficult to evaluate the effect of the new tendering process in the asphalt sector on a national level. The introduction of routines and increasingly familiarity with the terminology will hopefully improve the data quality and quantity.

As visible in table 1 there are discrepancies between the declared and measured emissions. This is being partially solved by introducing a bonus/penalty system where, when the effective CO_{2eq} differs by more than 5% from the declared one a bonus (5 NOK/kgCO_{2eq} for lower total emissions) or a penalty (10 NOK/kg CO_{2eq} for higher total emissions) is triggered [4]. Nevertheless, there is still a possibility for a contractor to exploit the system, giving a lower bid if they determine the profit from the project can outweigh the penalty, especially in areas where the market does not allow for strong competition. In these cases, the road owners are considering the possibility of introducing a maximum amount of acceptable kgCO_{2eq}/tonn asphalt, over which the contract will not be assigned.

The next steps, already initiated by the NPRA, are the extension of the CO2eq evaluation to the C1-C4 end of life stages and the introduction of the pavement service life in the tendering process to incentive the production of better mixes. In this case the adjusted bidding sum is divided by the expected service life and the final price per year determines the winner.

3 Analytical pavement design and analysis system

In Norway, pavement design is currently based on the N200 design guidelines [5]. An empirical design system developed by the NPRA in the 60ies. The system, based on material requirements and design tables/graphs, considers boundary conditions such as type of underground and traffic volume and partially taking into account local climate, traffic projections and material availability.

The current system is somehow straightforward but offers limited freedom for pavement design and does not take advantage of the local conditions and material to optimize the road structure. The advent of among others new non-regulated materials and technologies, emission requirements and leaner budgets have exposed the need for a better design tool able to customize and optimize a pavement structure based on the local conditions.

3.1 The VegDim project

In 2018 the NPRA started an ambitious R&D project, VegDim, with the goal of developing and implementing an analytical pavement design and analysis system. The result is the ERAPave PP program (Elastic Response Analysis of Pavements – Performance Predictions) in collaboration with the Swedish Transport Administration. The program is based on a response and a performance component that calculates the stresses and strains induced in the pavement structures due to traffic loading under the local climate conditions and predicts the pavement degradation as a function of time [6].

A large amount of construction and underground materials commonly used in Norway, have been tested to determine their response to induced stress and strains due to traffic and climatic loading. This information has been used to compile a material database available to all users. During the design process, this information will be combined will the available boundary conditions to determine the pavement service life according to the current regulations. A detailed description of the project can be found in [7, 8].

Although the program is being developed by the NPRA, it can, as the N200 design guidelines, be used by any road owner in Norway.

3.2 Challenges and future impact

While a working version is already available [6], the NPRA is expected to officially launch the Norwegian adaptation of ERAPave PP, as a part of its design methodology, at the end 2024. The tool will then be available for all road owners, consultants and industry, and will allow a better customization of the road structure based on the local conditions and available materials. It will help optimize the pavement structure, increase quality, accuracy and reliability, and provide long term reduction of financial and environmental costs [9].

On the road owner side, the system will allow for better maintenance and rehabilitation planning. ERAPave PP will be able to: generate degradation models for both new and existing pavements with known construction allowing for a long-term maintenance planning and resources optimization; create documentation of the user's choices and resulting consequences for future use and contribute to a conscious use of the resources. The users will be able to quickly create several design options for each section to analyze in terms of cost, resource use, service life and so on, and in the future, to create a proprietary material library.

However, given the complexity of the system, the introduction of ERAPave PP will generate several challenges for the NPRA, starting from establishing how and who will have the authority to submit and to approve the designs.

The introduction of a new system, based on models cryptic for many, could trigger insecurity in the end-user due to lack of trust in the quality and reliability of the results. During the last sixty years the industry has followed the N200 guidelines, browsing from table to graph to design an approved pavement structure based on empirical and cemented knowledge. The trustworthiness of ERAPave PP will be a critical factor for determining its success. To smoothen its implementation, the project group has already investigated the challenges encountered in USA and Sweden by MEPDG and PMS Objekt respectively. Validation of the results, guidelines updated according to the new design methodology and knowledge have been identified as important elements to look after [10]. The NPRA has started a series of seminars to gradually introduce the new design method to the larger audience, focusing on the background, data validation and implementation plan. In addition, an IT team has taken the task of rendering the tool user friendly to help ensure increased buy-in and adoption.

A deep knowledge about mechanistic-empirical design and understanding of ERAPave PP's approach will be necessary to verify the quality of the input data, understand the results and introduce proprietary materials. The NPRA will have to, in collaboration with education institutes, organize courses in advanced pavement design for professionals in both road owners, consulting and construction companies for a general knowledge update.

Potential new materials will require extended testing with equipment generally not available outside research institutes. How larger and smaller asphalt producers will have access to it is still not clear.

It is difficult to determine how long it will take for a shift towards the new tool to take place and how it will be received. Large funds and resources have been invested in this project and the hope is that it will encourage better customized solutions to extend the pavement service life while still looking at the economy and the environment.

4 Conclusions

The Norwegian pavement sector is working hard to contribute to the 2030 climatic goals. While there are many obstacles between today and its success, it has so far been clear that both road owners, consulting and construction companies are willing to collaborate and are daring to make big changes in an industry that has been so far advancing at a slow pace.

During the last three years, road owners and contractors have collaborated to reduce the CO_{2eq} emissions in the product and transport stage of paving already up to 30% compared to 2020. The expectation is to reach a CO_{2eq} value of about 20 kg/tonn asphalt. The introduction of the pavement service life among the awarding criteria will be crucial to achieve this goal and to stimulate the consultants and contractors to plan and design for longer lifetime. Central in its evaluation will be the soon to be launched analytic design and analysis system.

Introducing these new tools will help professionals in all positions make conscious choices where both the now and the future are taken into account.

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