Cirkularitet

Relevant litteratur – Urval ur VTI:s sökning

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78. Demonstration Project for Ground Tire Rubber and Post-Consumer Recycled Plastic-Modified Asphalt Mixtures
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81. Plastic Waste for Sustainable Asphalt Roads
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84. Airfield and Highway Pavements 2017: Testing and Characterization of Bound and Unbound Pavement Materials - Proceedings of the International Conference on Highway Pavements and Airfield Technology 2017
85. Stabilization of the Highway Slope using Recycled Plastic Pins
86. Use of Recycled Plastics in Asphalt Pavement Year 2
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89. Review of recycling waste plastics in asphalt paving materials

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114. Recycling of road materials into new unbound road layers - main practice in selected European countries
115. Recycled materials in roads and pavements: a technical review
116. Use Of Recycled Materials In Pavements: A PIARC Briefing Note

117. CEDR Resource Efficiency and Circular Economy.
118. CEDR TRANSNATIONAL ROAD RESEARCH PROGRAMME Utlysning 2017 - Nya material

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1 Övergripande

1.1 Circular materials in infrastructure: the road towards a decarbonised future

Materials on infrastructure projects, such as soil, stone and gravel, are used universally. But despite the large quantities of materials handled and the significant environmental, economic and social effects they have, the average citizen often has limited knowledge of how these resources are handled. With this report, we want to contribute to capturing the huge untapped potential of a more circular management of aggregates in infrastructure while meeting societal needs and the UN's sustainability goals. Additionally, this report aims to raise awareness of the huge impact of infrastructure, in terms of aggregates used and its environmental and financial costs. The report investigates how we can progress towards circular infrastructure through a more efficient management of aggregates. What can be done to minimise the amount used? How can we manage aggregates in a more circular manner within the value chain? And what are the key actions and roles? We look at current practice, barriers that exist and the best solutions to manage uncontaminated and buildable materials. It is vital that we close the knowledge gap that lies between society today and a more circular future. Infrastructure will be vital in the transition to a low carbon future.

https://www.swecogroup.com/wp-content/uploads/sites/2/2023/01/Circular-materials-in-infrastructure-Sweco-Urban-Insight-Report.pdf

1.2 Cirkulärt byggande – hinder och möjligheter: redovisning av regeringsuppdrag

I regleringsbrevet för budgetåret 2022 fick Trafikverket i uppdrag att analysera hinder och möjligheter för cirkulärt byggande med syfte minska klimatpåverkan inom verksamheten. Redovisningen visar att det finns pågående arbeten och att flera beståndsdelar finns på plats som bidrar till ett cirkulärt byggande. Resurseffektiva och giftfria kretslopp utgör en central komponent i strävan mot en cirkulär ekonomi. Det konstaterades att även om stora mängder material redan återanvänds och återvinns finns en förbättringspotential vilken kan utnyttjas för att minska verksamhetens klimatpåverkan. Bland de möjligheter som identifierades nämndes bland annat fortsatt utveckling av upphandling som styrmedel, tillgängliggörande av digital miljödata, tydliggörande av ansvarsförhållanden samt undanröjande av logistiska hinder och kunskapsbrister

http://trafikverket.diva-portal.org/smash/get/diva2:1726571/FULLTEXT01

1.3 Trafikverkets miljörapport 2017

Trafikverket har i uppdrag att verka för att de transportpolitiska målen uppnås och utifrån hänsynsmålet bidra till Sveriges miljökvalitetsmål. Trafikverkets vision – alla kommer fram smidigt, grönt och tryggt – är vår utgångspunkt i arbetet med att bidra till ett hållbart samhälle. Arbetet med att förbättra transportsystemet ur miljö- och hälsosynpunkt sker i samverkan med andra aktörer. Trafikverket tar årligen fram en miljörapport som kort beskriver tillståndet i transportsystemet inom Trafikverkets prioriterade miljöområden samt vilka åtgärder Trafikverket genomfört. Från och med 2016 innehåller rapporten ett temaavsnitt. I år är temat giftfria och resurseffektiva kretslopp i en cirkulär ekonomi.

https://trafikverket.ineko.se/Files/sv-SE/46633/Ineko.Product.RelatedFiles/2018_144_trafikverkets_miljorapport_2017.pdf

1.4 Infrastruktur: en branschrapport: IVA-projektet Resurseffektiva affärsmodeller - stärkt konkurrenskraft

Att styra om materialanvändningen till cirkulära resursflöden och ökad resurseffektivitet kräver en stor omställning av samhällsbyggnadssektorn. Dessa idéer är dock inte nya; de har funnits med sedan miljörörelsens rötter i slutet av sextiotalet. Det nya är att vi idag inser att det måste skapas nya affärsmodeller för att i grunden styra om de linjära resursflödena till cirkulära. För att det ska bli möjligt behöver de ekonomiska förutsättningarna förändras. Det måste vara lönsamt att vara resurseffektiv: det krävs en effektiv byggprocess, materialeffektiva metod- och materialval samt att man tar hänsyn till materialens livslängd och robusthet vid byggande och renovering. För befintliga anläggningar, fastigheter, konstruktioner och byggnader, där den största förbättringspotentialen ligger, är en effektiv användning och hög nyttjandegrad av störst och helt avgörande betydelse för omställningen. Denna rapport försöker belysa de förutsättningar, hinder och möjligheter som finns idag för att skapa ökad resurseffektivitet i sektorn. Den analyserar vilka styrmedel och incitament som

behöver införas för att i grunden ändra synen på resurser och skapa ökad konkurrenskraft för de affärsmodeller som bygger på framtidens cirkulära materialflöden – den cirkulära ekonomin.

https://www.iva.se/det-iva-gor/projekt-och-program/resurseffektiva-affarsmodeller/

1.5 A systemic perspective on transition barriers to a circular infrastructure sector

Due to the large use of resources and waste generation, the transition to a circular economy (CE) has become a major sustainability-related topic in construction. Intentions to achieve circularity are shared widely, but developments are slow in practice. This study identifies systemic barriers to the circularity transition from a social-technical systemic perspective. We used the Mission-oriented Innovation System (MIS) framework to provide insights into the problems and potential solutions underlying the circularity mission, the structure of the system and the system dynamics. Based on the analysis of a wide range of policy documents and twenty in-depth interviews with stakeholders in the Dutch infrastructure sector, three vicious cycles were identified that form persistent barriers to the transition: (1) the CE contestation cycle given the contested nature of the circularity mission; (2) the knowledge diffusion cycle given the need to adopt and diffuse knowledge; and (3) the innovation cycle when it comes to procuring and upscaling circular innovations. These barriers all relate to processual, organizational and institutional challenges rather than to technological ones. This indicates that construction managers, policymakers and researchers in the field of infrastructure circularity should shift their focus from specific circular solutions to creating appropriate conditions for changing current and introducing novel processes that facilitate circular ways of doing things.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85143131251&doi=10.1080%2f01446193.2022.2151024&partnerID=40&md5=506336e911c37415a818477eaf5745ab9e

1.6 Design validation via infrastructure health monitoring of the circular bridge project

As part of the Dutch Government's plan to implement schemes to make bridges re-usable, we are presenting a completed Rijkswaterstaat (Road Authority of the Netherlands) pilot project. The ambitious plan to become "circular" (i.e. re-usable) by 2030 requires to rethink the traditional construction process from the ground up. That means that the conventional way in which bridges are commissioned and build, is no longer applicable. The lifecycle process from design stage to execution and demolition needs to change. The Circular bridge pilot project demonstrates how bridge engineers designed the structure that utilizing standardized pre-cast concrete segments for a 200-year lifespan. These elements are assembled akin to Lego pieces and post-tensioned (PT) in the longitudinal and transversal directions. When the initial in-place service life of the bridge is reached (say 40 years), these blocks can be de-installed and re-assembled at a different location, hence the term circular. In order to confirm the design principles and overcome the requirement that the post-tensioning always needs to be bonded within the structure it was necessary to monitor the performance of the bridge during the execution phase. This, in EC terms, is referred to as "design-by-testing". To validate the design, a multi-component Infrastructure Health Monitoring (IHM) system was deployed. The IHM system consisted of camera control of traffic flows (CCTV) measuring vehicle counts, speeds and directions and featured the following sensing instrumentation: temperatures, bridge deflections, bird-gapping between the blocks and force monitoring. As part of the IHM system, alerts and alarms were programmed to be sent to engineers in case measurements exceeded pre-defined thresholds.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85101728049&partnerID=40&md5=6d7617cbb5248a2547da461b7e177535

1.7 Digital transformation to improve quality, efficiency and safety in construction of roads incorporating recycled materials

Raw materials and supplies have been subjected to much increased pressure due to the recent boom in infrastructure construction. These activities have caused more severe environmental damage. The construction and demolition of infrastructure assets accounts for around 30 per cent of global material consumption and waste generation. There are many benefits associated with recycling end of life materials and waste from these construction works. Recycling reduces disposal costs and carbon emissions. It also helps complying with environmental legislation and restrictions on what can be sent to landfill. It is expected that reliable recycling methods in the future should make efficient use of

comprehensive catalogue and databases of materials currently used in construction. Greater challenges when dealing with end of life infrastructure assets are often associated with the lack of, or incomplete, records about the materials used in the assets, such as since the design and construction phases, and throughout their serviceable lives. The increasing use of Big Data, smart sensors and automation open ways to build banks of material database into BIM (building information modelling) and other similar methods. This will provide detailed records of existing materials and their in-service history ahead of any future recycling, thus better informed during the design stage, and helps improving the effectiveness and quality of recycled products. Furthermore, road construction industry has been adopting the latest advancement in digitalization of pavement assessment technology. This new approach was aimed at obtaining substantial improvement in the productivity levels, quality and safety of the construction industry and minimizing impact on the environment. A new concept called "Construction 4.0"was subsequently introduced to implement this approach. This concept is often associated with key components such as smart automation, predictive intelligent, real-time data exchange, 4D/5D executions and immediate field-to-office stakeholder communication. These components are currently at early stages however, it has been evidenced that some of these components are being realized. This paper discusses the opportunity and potential benefits associated with the digital transformation in construction industry, specifically as means to promote quality, efficiency and safety in future recycling.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85097522258&doi=10.1088%2f1755-1315%2f599%2f1%2f012093&partnerID=40&md5=f1799ccca579cc48ab61b33736b3d465

1.8 Best practice expert advice on the use of recycled materials in road and rail infrastructure: part A technical review and assessment

This report (Part A:Technical Review and Assessment) is the first of two Best Practice Expert Advice on the Use of Recycled Materials in Road and Rail Infrastructure reports. Combined, these reports support the Australian Government's delivery of the National Waste Policy Action Plan 2019 objective to increase the use of recycled content in road and rail infrastructure and inform government procurement requirements. This report provides a review of government policies and actions that support the transition to a circular economy through the use of recycled materials in road and rail infrastructure. It also provides a technical examination of the application and uses of recycled materials; emerging opportunities; comparative performance to virgin materials; market maturity; supply; and estimated recycled content potential. The following materials are considered: 1. Crushed Concrete and Brick; 2. Recycled Crushed Glass (RCG); 3. Reclaimed Asphalt Pavement (RAP); 4. Crumb Rubber' 5. Ground Granulated Blast Furnace Slag (GGBFS); 6. Fly Ash; 7. Bottom Ash; 8. Recycled Solid Organics; 9. Recycled Ballast; 10. Recycled Plastics. Part B will provide further information on the environmental, economic and social impacts of using recycled materials in major infrastructure projects across the road and rail industries in Australia.

https://3003125.fs1.hubspotusercontent-na1.net/hubfs/3003125/ARRB%20Recycled%20Materials%20Best%20Practice%20Part%20A_Final%20June%202022.pdf

1.9 Best practice expert advice on the use of recycled materials in road and rail infrastructure: part B sustainability impacts report

This report (Part B: Sustainability Impacts Report) is the second of two Best Practice Expert Advice on the Use of Recycled Materials in Infrastructure reports. Combined, these reports support the Australian Government's delivery of the National Waste Policy Action Plan 2019 objective to increase the use of recycled content in road and rail infrastructure and inform government procurement requirements. This report reviews, assesses and reports on the environmental, economic and social impacts of using recycled materials in major infrastructure projects across the road and rail industries in Australia. The analysis focusses on the environmental impacts and provides summarised knowledge on the economic (quantified and non-quantified costs and benefits) and social implications of using recycled materials in road and rail infrastructure. The following materials are considered: 1. Crushed Concrete and Brick; 2. Recycled Crushed Glass (RCG); 3. Reclaimed Asphalt Pavement (RAP); 4. Crumb Rubber; 5. Ground Granulated Blast Furnace Slag (GGBFS); 6. Fly Ash; 7. Bottom Ash; 8. Recycled Solid Organics; 9. Recycled Ballast; 10. Recycled Plastics. This report also extends the information provided in Part A, by detailing barriers to the increased adoption of recycled materials and key recommendations to address these barriers. Part A provided a review of government policies and actions that support the transition to a circular economy through the use of recycled materials in

road and rail infrastructure. It also provided a technical examination of the application and uses of recycled materials; emerging opportunities; comparative performance to virgin materials; market maturity; supply; and estimated recycled content potential.

https://3003125.fs1.hubspotusercontent-na1.net/hubfs/3003125/ARRB%20Recycled%20Materials%20Best%20Practice_Part%20B_Final%20June2022.pdf

2 Återvinning av material

2.1 Miljöbedömning av att återanvända grus vid underhåll av grusvägar

I Sverige finns det ca 300 000 km grusväg varav drygt 90% är skogsbilvägar och enskilda vägar. För att bibehålla en god trafikkomfort och framkomlighet behöver vägarna underhållas, där bland annat nytt grus behöver tillföras med jämna mellanrum. En del av den grus som tillförs slitytan hamnar i vägkanten på grund av väderförhållande, vissa typer av vinterväghållning och att trafiken sprätter ut den. Genom att återvinna denna mängd går det att minska behovet av jungfruligt material, vilket i sig innebär att mindre grus behöver utvinnas och att färre transporter behövs från grusuttag till vägar som ska underhållas. I denna rapport presenteras en livscykelstudie över vilken effekt en återanvändning av grus vid kantskärning kan ha på de miljöeffekter som uppstår vid underhåll av grusvägar. Miljöbedömningen av detta genomförs med hjälp av en fallstudie där metoden livscykelanalys används. En vägsträcka som är en kilometer som representerar en generell grusväg används som fallstudie. Vägens funktion är att tillgodose att trafikanter med framkomlighet och körkomfort över tid och den funktionella enheten är i detta fall definierad till underhåll av 1 km grusväg under 4 år. De underhållsåtgärder som inkluderas är årligt barmarksunderhåll i form av bevattning, grusning, väghyvling inklusive dammbindning, samt hyvling av vägkanten som sker vart fjärde år. Tre olika alternativ vid vägkantshyvling undersöks. Referensalternativet är då ingen återvinning av grus sker. Mot detta jämförs två alternativ där man använder en uppsamlare och sorterare för att återanvända utkastat grus. Den ena uppsamlaren är SAGA och den andra är en nyutvecklad arbetsmaskin kallad ROLF. De miljöpåverkansfaktorer som undersöks är global uppvärmning och energibehov. Till det beräknas behovet av mängden jungfruligt grus.

http://liu.diva-portal.org/smash/get/diva2:1590190/FULLTEXT01

2.2 Stabilization of fine-grained soils in cold environment and exposed to seasonal frost: by-products as hydraulic binders

Denna doktorsavhandling handlar om stabilisering av finkorniga jordar med industriella restprodukter som hydrauliska bindemedel. Finkorniga jordar är mestadels inte lämpliga som terrass under väg- eller järnvägsbankar eller andra större konstruktioner, antingen på grund av stabilitetsskäl eller på grund av möjliga sättningar eller tjällyftningar. Därför blir finkorniga jordar ofta uppschaktade och deponerade. Genom stabilisering med hydrauliska bindemedel kan finkorniga jordar förbättras och därmed göras användbara på byggarbetsplatsen. Om industriella restprodukter kan användas som bindemedel uppnås flera hållbarhetsaspekter i kombinationen med stabilisering. Djupstabilisering av finkorniga jordar används mycket i Sverige för att höja stabiliteten eller för att minska sättningar. I länder med varmare klimat än Sverige används ytlig stabilisering relativt mycket inte bara för att förbättra jordens bärförmåga och reducera möjliga sättningar utan också för att reducera frostkänsligheten. Det är oklart hur stabiliserad jord påverkas av tjäle i kombination med låg härdningstemperatur, vilket leder till en minskad användning av metoden i länder med kallt klimat. Denna doktorsavhandling fokuserar på hur låg härdningstemperatur (+4°C till +7°C) i kombination med frysning och tinings cykler påverkar härdningsreaktionen av industriella restprodukter som hydrauliska bindemedel i finkorniga jordar. Tre serier med laboratorieanalyser utfördes på typiska finkorniga svenska jordar (lera, silt och siltig sand) som stabiliserades med två olika industriella restprodukter (från järnsvampstillverkning och från cementtillverkning) som bindemedel. Inverkansfaktorerna som varierades i dessa tre serier (bindemedelshalt samt härdningstid innan och efter frysning och tining) undersöktes i en statistisk analys.

FULLTEXT02.pdf (diva-portal.org)

2.3 Stabilisering av schaktmassor: nyttjande av bindemedelsstabiliserad lös lera som utfyllnadsmaterial

I Sverige transporteras schaktmassor bestående av lös lera i de flesta fall till deponi. Utvecklingstrenden i flera europeiska länder är att det ställs högre krav på användningsgrad av schaktmassor i takt med att deponiutrymme minskar. Att kunna använda schaktmassor inom projekt kan således komma att bli viktigare, även på platser med lös lera. Syftet med föreliggande projekt är att undersöka om stabilisering med bindemedel är ett hållbart alternativ för att hantera schaktmassor bestående av lös lera. Studien undersöker stabilisering som ett möjligt alternativ för att minska transporter och deponibehov samt möjligheten att nyttja den stabiliserade leran som utfyllnadsmaterial. Studien består dels av en laborationsdel, dels av en kalkyldel. Laborationsdelen omfattar inblandningsförsök med lera och bindemedel. Kalkyldelen omfattar en uppskattning av såväl kostnader som utsläpp av CO2-ekvivalenter för olika hanteringsalternativ. De alternativ som jämförs är transport av lera till deponi och användning av stabiliserad lera som utfyllnadsmaterial. Bindemedlen som har valts för laborationen baseras på dokumenterad effekt, tillgänglighet och miljöpåverkan. Totalt användes 5 olika bindemedel och lera från två platser i Göteborgsområdet (Pilekrogen och Ringön). Använda bindemedel var Kalkcement, Multicement, CKD, Merit samt Merit i kombination med byggcement.

SBUF 13618 Slutrapport - Stabilisering av schaktmassor bestående av lös lera LowRes.pdf

2.4 Utvärdering av styvhetsförändring i asfaltmassor med returasfalt, rejuvenatorer och polymerer

Returasfalt (RA) som återanvänds i nya beläggningar bidrar till att reducera miljöpåverkan från beläggningsarbeten. Att använda rejuvenatorer eller att använda ett mjukare bitumen är två metoder för att kompensera mot det hårdare åldrade bindemedlet i RA massorna. Rejuvenatorer reducerar styvheten och sprödheten i bitumen vilket förbättrar motståndet mot sprickbildning. Det saknas dock kunskap om beläggningar med rejuvenatorer ökar risken för initiala deformationer orsakade av tung trafik. Liksom för massor med rejuvenatorer är det inte undersökt hur massor med inblandat mjukare bitumen i RA påverkar den nytillverkade massans styvhet och deformationsstabilitet. Syftet med projektet är att utvärdera styvhetsförändring med tiden i labboratorietillverkade asfalt-beläggningar när rejuvenatorer eller mjukare bitumen används för att möjliggöra en ökad halt återvunnen asfalt. I detta projekt utfördes laboratorieundersökningar genom pressdragprovning, modalanalys och skjuvtest på fem olika asfaltmassor med RA, rejuvenatorer och polymerer. Laboratorieundersökningarna visar att det inte finns några tydliga skillnader i styvhetsförändring med tiden mellan de olika massorna under de första 3 veckorna (7 till 21 dagar). Men det finns skillnader i styvhetsutveckling med tiden på längre tidsperiod. Skjuvprovning utfördes ett år efter tillverkning av massorna och visar att kompensationsmetoderna såsom bitumenblandning eller rejuvenatorer ger liknande stabilitet för slutprodukten. Dessutom har polymermodifierade massor visat lägre modul vid låga temperaturer och högre modul vid höga temperaturer jämfört med massor utan polymermodifierat bindemedel, vilket är bra för motståndet mot sprickbildning vid låga temperaturer respektive för deformationsstabilitet vid höga temperaturer. Lagring och konditionering av provkropparna och samtliga mätningar utfördes i laboratoriemiljö vilket begränsar resultaten till att endast representera styvhetsförändringen som sker utan påverkan från klimat och trafik.

http://vti.diva-portal.org/smash/get/diva2:1501236/FULLTEXT01

2.5 Cirkulaer asfaltproduktion i Danmark

Hovedformålet med dette projekt har været at afdække mulighederne for at forbedre den cirkulære ressourceøkonomi gennem en forøget anvendelse af genbrugsasfalt i ny, varmblandet asfalt, uden at dette går ud over økonomi, funktionalitet og holdbarhed.

https://www2.mst.dk/Udgiv/publikationer/2018/10/978-87-93710-95-5.pdf

2.6 Tester av sulfidjord i stor skala: PM

MTC har för Trafikverkets räkning behandlat sulfat- och sulfidjord i fullskaleförsök med elfilterstoft vid MTC testanläggning. Syftet med försöken var att utröna möjligheten att stabilisera och/eller neutralisera den svavelhaltiga jorden med målet att den kan återanvändas i anläggningsändamål i eller utanför Trafikverkets verksamheter och projekt. En fördel med elfiltersoft är att det är en helt torr fraktion som är enkel att blanda in i andra massor. Elfilterstoft ska inte likställas med Mesakalk, vilket är en blöt fraktion med andra geotekniska egenskaper. Svavelhaltiga sedimentjordar (i denna rapport benämnda som ”sulfidjord”) är en naturligt förekommande jordart som finns längs landhöjningskusten runtom den Bottniska viken. Sulfidjord har låg hållfasthet, hög surhetsgrad och vid kontakt med luftens syre oxiderar jorden vilket bildar surt lakvatten varvid tungmetaller kan lakas ut. Så länge sulfidjordar befinner sig i den mättade zonen (under grundvattennivå) är de stabila och har ingen påverkan på den omgivande miljön. I en sulfidjord i den mättade zonen är det anaeroba, reducerande förhållanden och pH >7. Om sulfidjord exponeras för luftens syre, t.ex. i den omättade zonen (ovan grundvattennivå) eller när jorden grävs upp så oxiderar sulfidmineralen till sulfat. Då sjunker jordens pH-värde till under pH 6 (potentiellt pH < 4) och den jord som då bildas kallas för sur sulfatjord. De sura förhållandena frigör metaller och svavel från jorden, och lakvatten från sur sulfatjord kan även frigöra metaller från omkringliggande jordar. De urlakade ämnena och den sura miljön kan försvåra växtetablering och inverka negativ på vattenkvalitén i recipient. Detta har lett till att sulfidjordar måste hanteras särskilt om de påträffas vid t.ex. infrastrukturprojekt.

Slutrapport Test av sulfidjord i stor skala med bilaga.pdf (trafikverket.se)

2.7 Återvinning i beläggning med polymermodifierat bitumen, etapp 1

Återvinning av asfaltgranulat för användning i asfalt är ett prioriterat mål av både beställare och entreprenörer. Det ger både ekonomiska och miljömässiga besparingar till nytta för alla. En förutsättning för detta är dock att beläggningens tekniska egenskaper inte väsentligt försämras. Av försiktighet accepterar Trafikverket för närvarande en inblandning av högst 10 % asfaltgranulat i asfaltmassa tillverkad med polymermodifierat bitumen om inget annat anges i kontraktshandlingarna. Projektets övergripande syfte var att undersöka hur olika halter av återvunnet asfaltgranulat påverkar polymermodifierad asfalt för att om möjligt öka halten över nuvarande tillåtna 10 %. Syftet uppnås delvis genom att i laboratorium utvärdera egenskaper hos polymermodifierat bitumen (PMB) blandat med olika halter återvunnet bitumen. Målet är därför att undersöka vilka halter av återvunnet bitumen som kan användas utan att blandningen faller utanför specifikationen. Projektet omfattade laboratorieanalys av återvunnet och polymermodifierade bindemedel samt flera olika blandningar av dessa.

(Microsoft Word - \305tervinning i bel\344ggning med polymermodifierat bitumen, Etapp 1 utkast 5.docx) (trafikverket.se)

2.8 Återvinning av däck i anläggningskonstruktioner : : bättre resursutnyttjande av ett högvärdigt material

Gummi har särskilda egenskaper i förhållande till andra material. När uttjänta däck återvinns erhålls olika produkter som till stora delar har kvar sina gummiegenskaper. Det är till exempel mjukt, har isolerande och dränerande förmågor samt återfår sin ursprungliga form efter en belastning förutom att det är beständigt över tid. Dessa egenskaper kan utnyttjas för att framställa produkter och konstruktioner med unika kvaliteter, till exempel produkter som tål större deformation utan att gå sönder, som dämpar vibrationer och buller, som har en isolerande förmåga, har renande och stabiliserande förmågor. I anläggningsbranschen har man traditionellt mest utnyttjat antingen obundna granulära material, (sand och bergmaterial) eller bundna material (asfalt, betong). Gummimaterial i form av exempelvis granulat, däckklipp eller hela däck erbjuder möjligheter att utföra nya typer av anläggningskonstruktioner med speciella fördelar i förhållande till de traditionella

konstruktionerna. Välkända exempel på hur man skapat en ny typ av konstruktioner baserat på gummits speciella egenskaper är konstgräsplaner med gummigranulat och fallskyddande lekplatsbeläggningar. Det finns stora potentialer att utveckla anläggningskonstruktioner med unika egenskaper där det återvunna materialet utgör eller till del ingår och som kommer bli efterfrågat för sin funktion och lönsamhet. Ett grundläggande problem, oavsett tillämpningar, är att det handlar om två olika värdekedjor och någon naturlig länk för att knyta samman dessa saknas. Den ena värdekedjan är utförande och anläggande av väg och anläggningskonstruktioner och den andra är återvinning av avfall och restprodukter. Dessa värdekedjor har traditionellt helt olika fokus på syfte och mål med verksamheterna varför det önskvärda förhållandet med både ”push and pull” inte naturligt uppstår. För att skapa denna länk måste någon part ta ansvar för det behov och den roll som uppstår i skärningspunkten mellan värdekedjorna. Vem som tar denna roll är den springande frågan för vidareförädling, tillverkning och utförande där återvunna däck helt eller till del utgör råvaran.

http://vti.diva-portal.org/smash/get/diva2:1137164/FULLTEXT01.pdf

2.9 Askor för konstruktionsändamål : : slutrapport 2016-03-15

Vid förbränning av biobränslen och avfall genereras restprodukter, så kallade energiaskor, som kan användas som konstruktionsmaterial. I detta notat 8-2016 redovisas ett projekt som identifierat viktiga åtgärder i syfte att öka användningen av energiaskor för konstruktionsändamål. En stor andel av engergiaskorna har, i ursprunglig form eller efter sortering och behandling, goda konstruktionsmässiga egenskaper. För närvarande används energiaskor i Sverige till största delen som konstruktionsmaterial inom avfallsanläggningar; främst för sluttäckning av äldre avfallsdeponier. Men sluttäckningarna avslutas nu fortlöpande och behovet når sin kulmen inom de närmaste 5–6 åren. Därför behövs nya användningsområden för energiaskor, annars kommer askorna att deponeras i allt större utsträckning vilket är en dålig hushållning av resurser.Genom att använda energiaskor för konstruktioner, i exempelvis vägar, parkeringsplatser och för andra anläggningsändamål, kan man ersätta jungfruliga råvaror vilket gör energi- och avfallssystemet mer hållbart. Om inte andra avsättningsalternativ utvecklas ökar dessutom kostnaderna för askhanteringen, vilket belastar energiproducenterna och i slutändan också slutkonsumenterna.

http://vti.diva-portal.org/smash/get/diva2:922452/FULLTEXT01.pdf

2.10 Gröna koncept inom asfaltbeläggningar : : kunskapsöversikt

Valet av beläggning måste vid nybyggnad och underhåll ta hänsyn till en rad tekniska parametrar men även omgivnings- och arbetsmiljö. Många "gröna koncept" har utvecklats de senaste tio åren av entreprenörer, forskningsinstitut och Trafikverkets FOI-verksamhet. Det är viktigt att de goda exemplen valideras, sprids och implementeras i Regelverk och kunskapsdokument. Syftet med detta dokument är att lyfta fram de aktuella miljöfrågorna inom asfaltbeläggningar och dess påverkan på omgivningen. Dokumentet riktar sig i första hand till beställare, projektledare och specialister inom vägteknik. Bakgrundsmaterialet kommer från rapporter, FOI-projekt, Europaprojekt, NVF, handböcker, besök hos entreprenörer, seminarier med mera.

FULLTEXT01.pdf (diva-portal.org)

2.11 Återvinning av MJOG/MJAG i varmblandad asfalt (halvvarmt i varmt) : : Malmtransportväg Kaunisvaara – Svappavaara (MaKS)

Syftet med denna undersökning var att se i vilken grad man kan blanda in gamla asfaltbeläggningar som granulat i nytillverkad varmasfalt utan att försämra egenskaperna hos den nya beläggningen. Vägen mellan Kaunisvaara och Svappavaara behövde rustas upp på grund av kraftigt ökande malmtransporter med mycket tunga fordon (90 ton) framöver. För att se om den gamla beläggningen kunde användas som granulat i nytillverkad varmasfalt planerades fyra provsträckor med olika halter av gamla asfaltbeläggningar. De alternativ som testats är 0 procent inblandning (referensmassa) samt 10, 20 och 30 procent granulatinblandning. Asfaltmassa från dessa fyra provsträckor har skickats till

VTI för analys. Förutom grundläggande data av bindemedelshalt och kornkurva har bindemedelsegenskaper på återvunnet bitumen utförts (penetration och mjukpunkt) samt bestämning av hålrumshalt och styvhetsmodul vid +10 °C på borrkärnor från laboratorietillverkade plattor. Resultaten visar att materialet från provsträckorna med granulat är likvärdiga med referensmassan avseende styvhetmodul vid +10 °C. Undersökningen indikerar därmed att tekniken med att blanda återvunnen mjukasfalt i varmasfalt fungerat väl i halter upp till 30 procent. Vägen bör följas upp framöver för att studera eventuella skillnader mellan de olika provsträckorna över tiden med beaktande av hur omfattande den tunga trafiken kommer att vara längs denna vägsträcka.

http://vti.diva-portal.org/smash/get/diva2:840736/FULLTEXT01.pdf

2.12 Stålslagg i asfaltbeläggning : : fältförsök 2005 – 2012

Vid tillverkning av stål tillsätts kalk och dolomit som slaggbildare. Det innebär att slagg erhålls som biprodukt. Stålslagg används i många länder till bundna och/eller obundna lager i vägkonstruktioner. Denna rapport behandlar slagg från stålverket i Smedjebacken, EAF-slagg (Electric Arc Furnace), som ballast i asfaltbeläggning. Goda erfarenheter finns från Halmstad och Laholm där EAF-slagg använts till slitlager på högtrafikerade gator/vägar sedan början av 1990-talet. I Danmark har EAF-slagg från Smedjebacken använts frekvent i cirkulationsplatser och vägar/gator med intensiv trafik.

http://vti.diva-portal.org/smash/get/diva2:669318/FULLTEXT02.pdf

2.13 Re-road: End of life strategies of asphalt pavements,

Europe have more than 30 years of experience with reusing reclaimed asphalt in the production of new asphalt but there is still a possibility of optimising the processes. Much of the existing practice has been to recycle the surface course layer but generally it is included into a lower pavement layer and this does not make the optimum use of the premium aggregates and perhaps polymer modified binder present in the surface course layers. The Re-Road project has focussed on recycling asphalt at the highest level. The strategy of the project has been to address all major aspects which might hinder recycling: recovery processes, plant, mixture designs and understanding performance. The Re-Road reports show various aspects of recycling with a practical value that can and will help increase the reuse of reclaimed asphalt (RA) in a sustainable way. The summary includes some of the more notable general results achieved and additional results and achievements for the specialists could found in report. The environmental performance of reclaimed asphalt, a material that has already spent many years as part of a highway structure, had to be assessed. Furthermore, we a need to understand the environmental foundation for recycling asphalt in the first place; what benefits could it yield and what is the additional benefit of recycling surface course back into new surface course? Undertaking a life cycle assessment (LCA) was the most appropriate way to establish the necessary framework to answer these questions on an equitable, transparent basis. The results of the LCA proved that, above all, recycling to a bound course was significantly more environmentally advantageous than recycling to an unbound course. Appreciable extra benefit can be realised if high specification aggregates are preserved in their original application by surface-to-surface course recycling, due to the quarries that produce these specialised aggregates being widely spaced and hence requiring large transport distances for the aggregates. The moisture content that is sometimes present in reclaimed asphalt only mildly counteracts the recycling benefits. The results also indicate that low level recycling (just 15% to bound courses) is significantly more environmentally beneficial than warm mixing, particularly if the additives used to facilitate warm mixing are included in the analysis.

http://re-road.fehrl.org/index.php?m=48&mode=download&id_file=14968

https://projektdatabas.vti.se/cgi-bin/koha/opac-detail.pl?biblionumber=620

2.14 Utvärdering av polymermodifierat bitumen i returasfaltmassor

Zhu,Jiqing. VTI

Nu för tiden har återanvändning av returasfalt blivit vanligt i branschen. Enligt TDOK 2013:0529, vid varm nytillverkning, får mjukpunkten hos återvunnet bitumen för ingående returasfalt inte överstiga 65 °C. Detta krav fungerar vanligtvis bra för att utvärdera returasfalt som innehåller bara penetrationsbestämda bitumen. För returasfalt som innehåller polymermodifierat bitumen (PMB) kan det dock vara tveksamt att ha samma krav. Detta beror på att en hög mjukpunkt (till exempel över 65 °C) inte nödvändigtvis betyder dåligt för PMB – utan kan bero på den fortfarande effektiva polymermodifieringen. När asfaltbeläggningar med PMB når slutet av sin livslängd kommer återanvändning av returasfalt som innehåller PMB att bli ett problem. Med tanke på polymers höga koldioxidavtryck i PMB kommer bästa praxis att vara att bibehålla det höga mervärdet av PMB och återanvända den returasfalten i ny PMB-asfalt. För att underlätta detta kommer detta föreslagna projekt att identifiera effektiva tekniska parametrar för att kvalificera välpresterande returasfalt som innehåller PMB medan vägra dem av dålig kvalitet. Detta inkluderar också att hitta sätt att kvantifiera polymermängden i återvunnen PMB.

2.15 Clay-LCA: Aktiverade leror för betong – Bedömning av miljömässiga och ekonomiska konsekvenser och utmaningar för normativa processer

Mousavi,Marjan. RISE.

SN-Trafikverket 2022/42114

Cement- och betongindustrin i Sverige har ställts inför betydande press och ansträngt sig för att förbättra sin produktionseffektivitet samt deras miljömässiga och ekonomiska prestanda. En av de lovande lösningarna har varit användningen av kompletterande cementbaserade material (SCM), såsom kalksten, mald granulerad sprängslagg (GGBS), flygaska och kisestoff. Dessa material kan användas för att delvis ersätta klinker i cement eller cement i betong pga av deras puzzolaniska eller latenta hydrauliska reaktivitet. Men användningen av dessa material beror på deras lokala tillgänglighet och deras effektivitet och att kunna bytas ut. Ett av de material som finns i stora mängder i Sverige och samtidigt är tekniskt möjligt att använda som SCM är lera. Lera kan bli reaktiv efter kalcinering vid temperaturer mellan 700°C och 800°C eller genom aktivering via slipning. Eftersom lera är en naturresurs och måste utvinnas kan den orsaka miljö- och ekonomiska effekter. Därför fokuserar denna studie främst på att bedöma miljö- och ekonomisk prestanda för betong som innehåller bränd lera jämfört med en konventionell betong gjord av cement. LCA och LCC används som verktyg för att identifiera och kvantifiera miljö och ekonomiska bördor/fördelar med att använda bränd lera. LCA- och LCC-resultat gör det möjligt för oss att identifiera områden med förbättringar i livscykeln för betong när det gäller miljö och ekonomisk prestation.

2.16 Hållbar användning av sulfidförande berg i vägkonstruktion

Hellman,Fredrik. VTI

SN - Trafikverket 2022/104876

Projektet tar utgångspunkt i hållbart byggande av väginfrastruktur, cirkulär ekonomi och massbalans med fokus på att kunna nyttja så mycket bergmaterial som möjligt dvs även sådant som, idag av olika skäl, betraktas som olämpligt och körs på deponi. Omfattande mängder sulfidförande bergmaterial som produceras i samband med vägbyggnation skulle kunna användas direkt om det gick att säkerställa s k ringa risk för miljö och bibehållen funktion och beständighet hos vägkonstruktionen. Projektet är koordinerat med pågående projekt på Luleå Tekniska Universitet och fokuserar på de praktiska åtgärder kopplade till väg- och bankonstruktion som måste vidtas, dvs materialflöden till konstruktionen och funktion på strukturell nivå. Kort sagt, de tekniska förutsättningarna för en hållbar konstruktion och hållbart byggande. Projektet använder resultaten från de geokemiska studier man genomfört i Luleå och går vidare med väg/bankonstruktionen funktion och dess koppling till omgivningspåverkan genom lakning. Projektet tar fram nödvändiga underlag till kommande revision av Trafikverkets Handbok för hantering av sulfidförande bergarter.

2.17 Mot en klimatneutralt och resurseffektiv markstabilisering

Ahmadi,Arezou Baba. Chalmers

SN - Trafikverket 2021/130714

Konstruktion samt reparations- och underhållskostnaderna för transportinfrastruktur, byggd eller ska byggas på problematiska jordar, är enorma. För att förbättra hållfasthet och styvhet är avgörande för en livskraftig transport infrastruktur. En av de mest kända markstabiliseringsmetoderna, inkluderar stabilisering genom kemiska tillsatser, såsom inblandningar av kalk, cement och flygaska, förändrar jordens egenskaper, vilket resulterar i en bättre grundläggning. Då cementproduktion är förknippad med 8 % av de totala globala antropogena CO2-utsläppen, är nyckeln till en hållbar byggd transportinfrastruktur att minimera onödig användning av den. Eftersom den förväntade tillgången på de mest kända cementersättningsmaterialen som flygaska eller slagg också är begränsad inom en snar framtid, bör nya alternativa bindemedel undersökas. Detta har nyligen väckt ett stort intresse kring potentialen hos rikliga naturresurser såväl som industriavfall som kan användas som cementersättningsmaterial. Bland lämpliga alternativ har lågkvalitativa brända leror, träaska och kiseldioxidsand, framställda i processen för återvinning av fosfor från avloppsvattenslam, visat sig ha potential som alternativ för cementersättning. Detta är ett innovations/demonstrations forskningsprojekt som syftar till att säkra en transportinfrastruktur med lågt koldioxidavtryck med hänsyn till cirkulär ekonomi. Projektet drivs i samarbete med partners vid sidan av värdekedjan för produktion, optimering och tillämpning av nya kemiska tillsatser för markstabilisering med minsta möjliga cementinnehåll föreslås. En glimt av vad de senaste årens pandemi har gett oss visar att det är avgörande att agera medan det fortfarande finns tid och resurser, annars kan det komma en tid då all tid och resurser ska läggas på saker vi aldrig tänkt på. , och vi lämnas utanför med mål som inte längre kan uppfyllas.

2.18 Utvärdering av långsiktiga egenskaper och klimatavtryck av asfaltmassor med returasfalt och biobindemedel

Zhu,Jiqing. VTI

SN - Trafikverket 2021/79537

Vägmaterials långsiktiga egenskaper är viktiga för att säkerställa vägens långa livslängd och låga klimatpåverkan ur ett livscykelperspektiv. För att nå klimatmålen har det blivit ett fokus för vägbyggbranschen att använda en högre andel returasfalt i asfaltbeläggningar. Dessutom ökar användningen av biobaserade bindemedel i stället för fossilbaserad bitumen i asfalt för att ytterligare minska koldioxidavtrycket från asfaltproduktion. Dessa nya åtgärder leder vanligtvis till bra initiala klimateffekter i ett tidigt skede. Ett långsiktigt perspektiv är dock oumbärligt för att utvärdera livscykelkostnaden och klimatavtrycket för dessa nya åtgärder. Detta projekt syftar till att utvärdera asfaltens samt bindemedlets prestanda och relaterade egenskaper ur ett långsiktigt perspektiv när returasfalt och biobindemedel användas i asfalten. Detta kommer att hjälpa till att förstå rollen för returasfalt och biobindemedel för att minska koldioxidutsläppen ur ett livscykelperspektiv (inte bara den initiala utsläppen under byggprocessen). Egenskaperna som ska undersökas är främst utmattningsegenskaper och lågtemperaturegenskaper hos asfalt samt bindemedel efter åldring. Där gäller mekaniska och DSR-analyser på asfalt respektive bindemedel. De förväntade resultaten kan hjälpa till att förstå effekter av ökad andel returasfalt och användningen av biobindemedel på utveckling av asfaltbeläggnings tillstånd.

2.19 Metodik för stabilisering av muddermassor

Lindh,Per. LU

SN - Trafikverket 2021/22354

Byggande av infrastruktur innebär stor klimat- och miljöbelastning där en bidragande faktor är användning av högkvalitativa fyllnadsmaterial såsom krossad sten. En möjlig åtgärd, för att minska klimat- och miljöbelastningen kopplad till byggande av infrastruktur, är att istället använda restmaterial som fyllnadsmassor. Med ökad fokus på att åtgärda föroreningsspridningen har stabilisering/ solidifiering blivit ett alternativ för att både ta hand om föroreningen men också att återanvända muddermassorna i olika typer av konstruktioner. Användning av stabiliserade muddermassor minskar inte enbart miljöbelastningen direkt kopplad till byggande av stora infrastrukturprojekt utan omhändertagande av muddermassorna, som ofta är förorenade, fungerar som skyddslösning mot urlakning till vattendrag. Detta eftersom massorna i annat fall läggs på deponi. Projektet kommer att resultera i praktiskt tillämpbara riktlinjer för stabilisering av förorenade muddermassor där minimering av läckaget av föroreningar är en avgörande faktor. Projektet kommer därför att bidra till en miljömässigt och kostnadseffektiv hållbar utveckling av samhället i stort genom

att resultaten kan användas för att optimera nya projekt med hänsyn till naturresurser och behandling av förorenade massor. Projektets resultat svarar därför väl upp mot Trafikverkets krav inom det aktuella delområdet ”metoder för att minimera negativ påverkan och utveckla positiva miljökonsekvenser.

2.20 BETCRETE 2.0

Lindgren,Åsa. Trafikverket

SN - Trafikverket 2020/95596

År 2050 förväntas 70% av världens människor bo i storstadsregioner. Med växande behov av investeringar i infrastruktur och bostäder ökar betonganvändandet exponentiellt. Redan idag används mer än 30 mdr t betong/år - cement står för ca 6% av världens CO2-utsläpp. Det kräver en effektiv industriell omställning med kraftiga utsläppsminskningar från cement- och betongbranscherna för att producera limatneutral betong. Projektet syftar till att accelerera implementeringen av de ambitiösa målen för ett klimatneutralt byggande med betong. Projektet bidrar till att den klimatneutrala betongen finns på marknaden 2030 och att den används i hela Sverige 2045. Utveckling av nya betongrecept, alternativa bindemedel samt cirkulärekonomi ska följas upp med hållbarhetsindikatorer. Projektet kommer vidare att analysera och bearbeta det glapp som föreligger inom teknik- och materialutveckling samt regelverk, praxis, marknadsdrivna behov och processer, exempelvis inför tillståndsprövningar, innovationsupphandling och finansiella omställningslösningar. Branschen stärker därigenom sitt partnerskap i syfte att bygga legitimitet, samsyn och stöd för industrins värdeskapande verksamhet samt för de tids- och kapitalkritiska investeringar som dess hållbara omställning kräver. De viktigaste aktörerna är cement och betongtillverkare, branschorganisationer, myndigheter, forskare och innovatörer, entreprenörer, beställare och finansiärer.

2.21 Lignin i asfaltbeläggning: provväg med fossilreducerat bindemedel

Lundström,Robert. NCC Roads AB

SN - Trafikverket 2020/107144

Projektets överordnade syfte är att väsentligt minska fossilberoendet vid vägbyggnad och -underhåll. Fossilfria transporter är en gemensam målsättning för entreprenörer och Trafikverket. För asfalttillverkning har omställningen till biogena bränslen gått fort och i naturlig följd står nu att reducera fossilberoendet i bindemedlet och t.o.m. möjliggöra en tillfällig koldioxidsänka. Målsättningen med projektet är att skala upp tillverkning av ett bindemedel baserat på sulfatlignin (lignin tillsammans med bitumen i första skedet) och genom en provväg kvantifiera effekten av detta innovativa bindemedel i asfaltbeläggning. Lignin är en skogsprodukt. Det är ett samlingsnamn för flera olika typer av lignin. Den typ som idag är kommersiell i stor skala är en biprodukt som separeras från sulfatmassaproduktion. Andra potentiella, men idag inte kommersiellt tillgängliga ligniner från skogen i stor skala, är de som erhålls som en biprodukt från bioraffinaderier.

2.22 Utveckling av effektiva och relevanta metoder för bedömning av bergmaterial innehållande metallförande sulfidmineral

Miskovsky,Karel. Envix Nord AB

SN - Trafikverket 2019/120115

Praktiska erfarenheter med hantering av sulfidförande bergmassor (Envix 2007–2019) som enligt nuvarande bedömningsmetoder (Trafikverkets handbok för hantering av sulfidförande bergarter, Trafikverket 2015:057) klassas som låghaltiga har visat att motsvarande krossprodukter har gett upphov till betydande skador på biotoper och närmiljö genom försurning och utsläpp av miljöfarliga tungmetaller. Miljöproblem uppstår speciellt vid användning av sulfidmineraliserad bergkross som utfyllnad av exploateringsytor, magasinering i upplag och i väg- och järnvägskonstruktioner. Problemet har aktualiserats i samband med stora infrastruktursatsningar såsom förbifart Stockholm och Norrbotniabanan då stora volymer av överskottsmassor hanteras. De hittills genomförda undersökningarna (Envix 2019, pågående projekt) tyder på att, vid krossning, anrikas sulfidmineral i krossproduktens finfraktion, vilket ökar deras reaktivitet beroende på ökad specifik yta. Dessutom

jämnfördelas sulfidmineral i ballastprodukten i samband med krossning och siktning. Beroende på sulfidmineraliseringarnas variationer i mineralsammansättning, koncentration och grundvattenförhållanden är hantering av sulfidförande bergmaterial platsspecifik. Projektet avser att utveckla och verifiera nya, problemanpassade, effektiva provtagnings-, provberednings- och analysmetoder samt ge förslag till klassificeringssystem för sulfidförande bergmassor och bergkross. Vidare kommer projektet att bidra till komplettering och breddad tillämpning av Trafikverkets publikation 2015:057 samt utgöra underlag för bestämning av rekommenderade riktvärden. För att i hög grad minska sulfidförande bergmaterialens negativa miljöpåverkan och därmed förbättra hushållning med naturresurser ska forskningen vidare fokusera på utveckling av effektiva och hållbara för- och efterbehandlingsmetoder.

2.23 BVFF Uppföljning av provsträckor med återvinningsmaterial på E20 Hova

Ahmed,Abubeker. VTI

SN - Trafikverket 2019/28612

Detta projekt syftar till att följa upp och utvärdera tillstånd och prestanda på provsträckor med utökad andel returasfalt på E20 Hova. I provsträckorna används olika halter av återvinningsmaterial med bl.a. rejuvenatorer, bitumenblandning och PMB. Uppföljningen sker genom respons- och fältmätningar, laboratorieundersökningar av prov uttagna från konstruktionen. Beräkning av teoretiska livslängder med olika konstruktioner baserade på representativa materialegenskaper (erfarenhetsmässiga eller laboratoriebestämda egenskaper) utförs. Resultatet kan användas som beslutsunderlag och erfarenhetsstöd för regelverket kring Bitumenbundna lager samt LCC-beräkningar som inkluderar återvinning.

2.24 Klimat- och miljösmart hantering av sulfidjord

Mácsik,Josef. Ecoloop AB

SN - Trafikverket 2017/93590

Syftet med projektet är att förbättra produktionsmetoderna för anläggningsarbeten genom att öka återanvändningen av sulfidjord och därmed minska behovet av långa transporter och deponering. Målsättningen är att utveckla en bättre bedömningsmodell som delar in sulfidjord i fyra olika klasser utifrån lämplighet att återanvändas utifrån jordens miljögeotekniska egenskaper, och sedan i full skala utreda möjlighet att återbruka sulfidjord. Målsättningen är att förenkla en miljösäker användning av sulfid-/sulfatjord som är ekonomiskt och tekniskt genomförbar. Projektet genomförs inom fyra delmoment, som kommer att pågå överlappande. Projektets delmoment: 1) ta fram klassning av sulfidjord utifrån försurningspotential, försurningshastighet och pH-tillstånd; 2) två applikationer undersöks med avseende på miljögeotekniska egenskaper i laboratorium och ur ett miljösystemperspektiv; 3) demonstration av klassning och två hanteringsalternativ i full skala; 4) resultaten kommuniceras med viktiga aktörer - miljömyndigheter, entreprenörer, konsulter.

2.25 Utvärdering av möjligheten att återanvända lera med innehåll av kalk och cement

Hartmann,Hanna. Structor Miljö Väst AB

SN - Trafikverket 2016/80466

Projektets syfte är att utvärdera om lera med innehåll av KC kan återanvändas vid skyddstäckning av gamla deponier utan risk för omgivningspåverkan. För att bedöma det kommer prover innehållande lera med KC att analyseras med avseende på kemisk sammansättning samt laktestas för att utvärdera risk för påverkan på miljö. Provtagningar utförs på ett förutbestämt område inom projekt Marieholmsförbindelsen. Provtagningen genomförs som samlingsprovtagning, dvs att flera stickprover blandas till ett prov, i den mån det är möjligt i lera. Detta genomförs med hjälp av grävmaskin i ca 30-40 provgropar. Ett antal provgropar kontrolleras endast visuellt.

30-40 prover skickas till ett ackrediterat laboratorie för analys och laktester som ska utgöra underlag för att bedöma risk för omgivningspåverkan.

https://bibliotek.vti.se/cgi-bin/koha/opac-detail.pl?biblionumber=284914

3 Masshantering

3.1 Masshantering: indikatorer och nyckeltal för incitament för reducerad klimatpåverkan vid upphandling

Metodik för styrning av cirkulär masshantering i Trafikverket är inriktad på moment som genomförs i projekteringsskedet. Det saknas metodik för hur indikatorer och nyckeltal kan föras över till entreprenaden. För att förbättra krav och incitament i entreprenadupphandling måste krav som är upphandlingsbara och uppföljningsbara i entreprenaden utvecklas. Syftet med detta projekt är att, i en förstudie, ta fram förslag på indikatorer och nyckeltal för upphandling som kan användas för att sätta krav och ge incitament som kan föras in i Trafikverkets upphandlingar för att förbättra masshanteringen, såväl i planeringen av projekt som i själva utförandet. De krav och incitament som på längre sikt ska arbetas fram ska kunna användas vid upphandlingar och därmed bidra till att entreprenörer kommer att arbeta mer cirkulärt, hållbart och innovativt med masshantering än i dagsläget. Huvudsyftet är att upphandlingsförfarandet ska bidra till att uppnå Trafikverkets mål att infrastrukturen ska vara klimatneutral senast år 2045. Arbetet utgörs av en omvärldsanalys som baseras på internationell och nationell litteratur, masshanteringsrapportering samt intervjuer. Från omvärldsanalysen framgår att regelverken kring uppgrävda massor inte är tydlig, men att massorna klassas som avfall i de flesta länder. Detta leder i sin tur till att massorna inte återvinns i så hög grad som är teoretiskt möjligt och inte heller så högt upp som möjligt i värdekedjan. För att förbättra detta krävs tydligare incitament, indikatorer och nyckeltal samt redovisningsverktyg och guidande material från Trafikverket. I detta projekt har förslag på indikatorer och nyckeltal tagits fram. Dessutom har en Excelbaserad prototyp för hur flera av dessa kan redovisas tagits fram. Denna ska när den färdigställts kunna användas såväl inför en upphandling som för att användas för att följa upp och utvärdera masshantering i ett projekt. Rapporten ger också förslag på fortsatt arbete för att utveckla prototypen för utvärdering av masshantering på projektnivå och ur ett samhällsekonomiskt perspektiv.

http://vti.diva-portal.org/smash/get/diva2:1712788/FULLTEXT01.pdf

3.2 Entreprenörsråd för en hållbar masshantering

Bygg- och anläggningsbranschen är den bransch som har störst klimatpåverkan. För att kunna nå klimatneutralitet 2045 så kommer branschen behöva genomgå ett starkt förändringsarbete där resursoptimering, materialval och användning av maskiner och fordon kommer stå i fokus. Hantering av jord- och bergmassor utgör en betydande del av klimatpåverkan i projekten. Omsättningen av jord- och bergmassor i byggprojekt drivs av de stora behoven av schaktning och av konstruktionsmaterial vid byggande av hus, vägar och andra anläggningar. Vid byggnation hanteras schaktmassor i varierande mängd och av varierande karaktär. Endast en mindre del av de uppschaktade massorna återanvänds och en stor del deponeras. Studier visar att omkring 16 procent av klimatpåverkan från ett anläggningsprojekt kan kopplas till masshanteringen. För att minska miljöeffekterna av masshanteringen så behöver återvinningen av massor öka. I detta projekt har fokus varit på att ta fram konkreta råd till entreprenörer för en mer hållbar masshantering och hur digitala verktyg kan användas för att förbättra masshanteringen. Projektets metod har bestått av att söka och sammanställa information via litteratur, rapporter och webbsidor, samt genom workshops tillsammans med alla de aktörer som medverkat i projektet. Resultaten från projektet är ett antal entreprenörsråd inom områden som Ökad samordning i värdekedjan, Kunskapshöjande åtgärder, Lagar och tillstånd och Ekonomiska incitament och affärsmodeller. Projektet har också sammanställt information om digitala arbetssätt och tjänster inom masshantering. Projektet har identifierat ett antal olika digitala lösningar som kan bidra till en mer hållbar masshantering och ökad spårbarhet för massorna. Lösningarna består av bland annat standarder för digitala meddelanden och stöd i form av appar och system och tjänster som företag erbjuder. Även ett flertal verktyg för hållbarhetsbedömning av masshantering har identifierat och som kan nyttjas i olika delar av byggprocessen. I projektet genomfördes också fördjupad analys och framtagande av ett förslag/koncept på nytt digitalt arbetssätt som kan öka spårbarheten för massor i projekt.

ENTREPRENÖRSRÅD FÖR EN HÅLLBAR MASSHANTERING (sbuf.se)

3.3 Masshantering i klimatkalkyler: förslag till förbättrade beräkningar av masshantering i tidiga planeringsskeden med Trafikverkets modell Klimatkalkyl

Masshantering (schakt och fyll av jord och berg) kan bidra mycket till ett byggprojekts miljöpåverkan. Masshanteringens miljöpåverkan måste därför beräknas på ett representativt sätt redan i tidig planering. Trafikverket använder verktyget Klimatkalkyl för att beräkna byggprojekts klimatpåverkan och energianvändning. Detta projekt föreslår hur Trafikverket skulle kunna förbättra Klimatkalkyls beräkningar av masshanterings klimatpåverkan och energianvändning i tidiga planeringsskeden. Förslaget baseras på (1) inventering av befintliga livscykelanalys (LCA)-verktyg och en sammanställning av tidigare forskningsresultat, (2) identifiering av vilka aspekter av masshantering som har störst behov av förbättrad indata och (3) identifiering av approacher som skulle kunna göra Klimatkalkyls beräkningar av masshantering mer representativa och analysering av hur Klimatkalkyl skulle behöva ändras för att kunna implementera dessa approacher. Ett 70-tal LCA-verktyg identifierades genom en litteraturstudie. Det verkar som att verktygen Geokalkyl (från Trafikverket) och Tidligfaseverktøy for bane (från norska Bane NOR) skulle vara de mest relevanta i tidig planering. Denna rapport sammanfattar även resultat från forskningsprojektet Optimass forskning om masstransporter i Sverige. Dessa verktyg och forskningsprojekt ligger till grund för de approacher som utreds i projektet. Följande aspekter av masshantering verkar ha ett behov av förbättrade schabloner eller en utredning av schablonernas representativitet: krossning, dumper, grävmaskin, lastbil och borrning. Dels bör Trafikverket utreda varför schablondata skiljer sig väsentligt mellan Geokalkyl och Klimatkalkyl, dels önskar entreprenörer tillägg eller förtydligande till Klimatkalkyls befintliga schabloner och dels kan Klimatkalkyls transportavstånd skilja sig väsentligt från faktiskt transportavstånd i byggprojekt. Dessutom bör Trafikverket undersöka om Klimatkalkyl borde inkludera arbetsmomentet vält i byggdelarna Jord Fall A, fyll och Jord Fall B, fyll. Tre approacher som skulle kunna förbättra Klimatkalkyls beräkningar av masshantering identifierades och analyserades: (1) använda resultat från verktyget Geokalkyl (baserat på geografiska informationssystem) så att projektspecifika schakt- och fyllvolymer kan användas i Klimatkalkyl, (2) utnyttja samband mellan projektets svårighetsgrad och masshantering så att defaultdata kan representera byggprojekts svårighetsgrad och (3) använda region- eller masspecifika transportsträckor för att få mer projektspecifika beräkningar av transportrelaterade utsläpp och energianvändning. Alla dessa approacher skulle kunna förbättra beräkningarnas representativitet, men endast Geokalkyl kan implementeras utan vidare datainsamling.

http://kth.diva-portal.org/smash/get/diva2:1656220/FULLTEXT02

https://projektdatabas.vti.se/cgi-bin/koha/opac-detail.pl?biblionumber=3978

3.4 Energieffektiv och cirkulär masshantering i Trafikverket genom extern samverkan: fallstudie Södertörn

I samband med anläggningsarbeten schaktas stora mängder massor ut och stora mängder material från täkter köps in. Många projekt strävar efter massbalans för dessa flöden inom det egna projektet, men samordningen mellan projekt är generellt mycket liten. Detta gör att stora mängder massor transporteras långa sträckor, stora mängder massor tas ur täkter och att stora mängder massor körs till deponier. Detta medför stora kostnader, utsläpp av växthusgaser, trängsel, ökade trafikrisker, buller och andra störningar. Teoretiska studier visar att transporter och växthusutsläpp kan minskas med uppemot 30 % genom att olika projekt använder sig av gemensamma samordningsytor för masshantering där material kan förädlas och omfördelas mellan projekten. Detta projekt har som mål att se över möjligheterna för Trafikverket att använda samordningsytor för masshantering. Tvärförbindelse Södertörn och kringliggande utvecklingsprojekt hos kommunerna har använts som fallstudie för att illustrera arbetsmetoden samt potentialen för effektivare materialanvändning och minskning av transporter. För att kunna beräkna massuppkomst och materialbehov och sedermera potentialerna i arbetsmetoden har beräkningsmodellen Optimass använts. I fallstudien

Tvärförbindelse Södertörn har fokusområden identifierats som är lämpliga för att samordna massor. Studien visar att samordning av massor mellan Tvärförbindelse Södertörn och kommunala exploateringsprojekt ger samhällsnyttor i form av minskat uttag av ändliga resurser, minskade transportsträckor, klimatutsläpp, och kostnader för transporter jämför det dagens metod att varje projekt hanterar massor internt inom projektet. För att kunna implementera samordnad masshantering i Trafikverket föreslås åtgärder på tre nivåer: nationell, regional och på projektnivå. På regional nivå föreslås arbetet med samordningsytor för masshantering ligga på verksamhetsområde Planering som har uppdraget och verktygen för en regional överblick på projekten, den regionala massbalansen och planförutsättningar. Verksamhetsområde Planering föreslås inrätta en ny funktion för detta arbete. Åtgärderna som behövs på projektnivå för att möjliggöra samordning av masshanteringen lyfts in i projektet genom projektbeställningen och bygger i hög grad på de massbalanser som tas fram på regional nivå och skickas in som underlag till ÅVS:erna. Detaljeringsgraden i masshanteringsplanen ökar i takt med att projekteringen fortskrider.

Slutrapport Energieffektiv och cirkulär masshantering.pdf (trafikverket.se)

3.5 Cirkulär masshantering i samverkan

Vennström,Anders. SWECO Sverige AB

SN - Trafikverket 2022/62072

Hanteringen av jord- och bergmassor vid byggande och underhåll av infrastruktur står för stora kostnader och växthusgasutsläpp och det blir allt svårare att hitta avsättning för massor när materialet inte kan användas i det egna projektet. Flera forskningsprojekt har visat på att en mer hållbar och konkurrensmässig masshantering kan uppnås med en bättre samordning av masshanteringen mellan olika investeringsprojekt och andra byggprojekt på regional nivå. En samordning av massor mellan Trafikverkets projekt eller med andra externa byggprojekt är dock svår att få till i praktiken bl.a. för att det inte finns ytor för lager och hantering i nära angränsning till byggprojektområdena samt att det inte finns etablerade former, arbetssätt och affärsmodeller för samordning mellan olika aktörer. Det finns också frågetecken kring lämpliga driftsformer för tillfälliga samordningsytor. För att uppnå en mer hållbar masshantering inom Trafikverket ska det inom detta projekt tas fram ett förslag på hur cirkulär masshantering med aktörssamverkan kring tillfälliga och närliggande samordningsytor ska byggas upp, styras och förvaltas generellt. I detta ingår bl.a. att identifiera och ta fram förslag på samverkansformer, affärsmodeller, driftsformer för tillfälliga samordningsytor samt organisation och process för styrning och implementering av cirkulär masshantering i Trafikverket. Stora delar av arbetet bygger på intervjuer, workshops och möten för att få en delaktighet och samverkan med berörd bransch, kommuner och myndigheter.

3.6 Materialflöden och indikatorer för cirkulär ekonomi-MICE

Lundberg,Kristina. Ecoloop AB

SN - Trafikverket 2021/127865

Detta projekt önskar bidra till Trafikverkets arbete för en ökad cirkulering av byggmaterial. Information om total materialanvändning är idag begränsad vilket gör det svårt att rapportera såväl som att prioritera åtgärderna för mer cirkulärt byggande. För att kunna följa och utvärdera hur hinder för cirkulärt byggande kan överbryggas behövs utvecklad och övergripande kunskap om nuläge och hur materialflödet ska kunna mätas över tid. Projektet genomförs i två steg. En inledande del med omvärldsanalys och förarbeten till materialflödesanalys levereras som ett underlag till Trafikverkets regeringsuppdrag för cirkulärt byggande (uppdrag 9 i TrVs regleringsbrev, 2022). I den andra delen utvecklas förslag på indikatorer, samt förutsättningar som behöver skapas i planeringsskedet för att öka möjligheterna till cirkulärt byggande, undersöks. Det långsiktiga målet är att förstärka Trafikverkets löpande tillståndsbeskrivningar och kunna följa upp cirkulariteten av byggmaterial kontinuerligt i linje med den nationella strategin och handlingsplanen för cirkulär ekonomi.

3.7 Hållbar masshantering - indikatorer och nyckeltal för incitament för reducerad klimatpåverkan vid upphandling

Andersson-Sköld,Yvonne. VTI

SN - Trafikverket 2021/55211

Syftet med detta projektförslag är att, i en förstudie, ta fram preliminära förslag på indikatorer och nyckeltal som kan användas för att sätta krav och ge incitament i Trafikverkets upphandlingar för att förbättra masshanteringen, såväl i planeringen av projekt som i själva utförandet. De krav och incitament som på längre sikt skall arbetas fram kunna användas vid upphandlingar och därmed bidra till att entreprenörer kommer att arbeta mer cirkulärt, hållbart och innovativt med masshantering än i dagsläget. Huvudsyftet är att upphandlingsförfarandet ska bidra till att uppnå Trafikverkets mål att infrastrukturen ska vara klimatneutral senast år 2045.

3.8 Cirkulära materialflöden i anläggningskonstruktioner

van Praagh,Martijn. LU

SN - Trafikverket 2021/43882

Målet med projektet är att ta fram verktyg för att beskriva och bedöma relevanta och vetenskapligt underbyggda miljökriterier för mineraliska, lätt förorenade material så att dessa ska kunna bilda cirkulära flöden snarare än att bli avfall, i enlighet med Sveriges och Trafikverkets ambitioner respektive mål (se "Cirkulär ekonomi - strategi för omställningen i Sverige"). även kallade end of waste-kriterier. Riskerna med återvinning av massorna bedöms, vilka faktiska skador eller risker som har uppkommit tidigare, samt vilka olika hinder och möjligheter det finns för olika massor/material att bli produkter snarare än att förbli ett avfall. För att fylla kunskaps- och dataluckor genomförs provtagning, analys och testning av de materialtyper som anses mest relevanta för Trafikverket. Testerna ska på ett vetenskaplig och verifierbart sätt återspegla de viktigaste hälso- och miljöriskerna som återvinningen kan ge upphov till. Projektet genomförs som ett doktorandprojekt.

3.9 Cirkulär masshantering enligt Optimass

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Syftet med föreslaget projekt innebär att vidarutveckla, och verifiera och lägga upp en strategi för implementering av forskningsresultat från projektet Optimass arbetspaket 3 (AP3) offentlig och privat materialförvaltning avseende jord- och bergmaterial i samverkan med nyckelaktörer. Utgångspunkten i Optimass är att betrakta staden som ett urbant lager och även se de material som genereras som överskott idag, som en resurs i framtidens byggande och som komplement till det som bryts och förädlas i täkter. Resultat från Optimass visar bl a att Trafikverket är bra på att optimera masshantering inom sina enskilda projekt, men att det sker en mycket liten samordning mellan Trafikverkets egna och andras projekt. Avfallsbegrepp och klassificering av jord efter typ och föroreningsgrad bromsar sådan samordning samtidigt som funktioner för logistik och materialhantering flyttas allt längre bort med ökat buller, transportarbete och klimatpåverkan som effekt. I Optimass har visats att 1) en ökad grad av samordning mellan projekt ger betydande vinster i ekonomi, energi och klimat 2) att lågkvalitativa material med ”enkla” åtgärder kan uppgraderas för användning, 3) att utveckla teknik för ”tyst” krossning och kvalitetskriterier för entreprenadberg skulle spara resurser och öka produktivitet, 4) att regional samordning och lokala lösningar för etablering av logistik- och materialhantering avsevärt skulle förbättra förutsättningarna för bättre resurshantering. I Optimass AP3 har ett verktyg och innovativa lösningar utvecklats för att möjliggöra en effektivare hantering av jord- och bergmaterial. Med det så kallade prognosverktyget kan massbalansen för ett geografiskt område, t ex en delregion med ett eller flera större infrastrukturprojekt samt olika bostadsprojekt, fastställas i ett mycket tidigt planeringsskede. Prognosverktyget ger kunskap om den mängd ballast som erfordras för byggande samt vilka mängder massor som genereras vid byggandet, detta kan användas som komplement till den vanligen goda kännedomen om material i det egna enskilda projektet. Prognosverktyget är uppbyggt på ett liknande sätt som Trafikverkets geokalkyl men inkluderar även andra, externa och interna, byggprojekt. Att verktygen är uppbyggda på likande sätt förenklar möjligheten till användning med obrutna dataflöden. Prognosverktyget och kunskap om den regionala massbalansen ger ”materialägare” en unik möjlighet att planera och samordna massor

mellan egna och andras närliggande byggprojekt och kan därmed effektivisera och underlätta återvinning av material mellan olika projekt, och på så sätt reducera tunga transporter och buller.

3.10 Utvärdering av möjliga transportalternativ av schaktmassor: alternativt hanteringssätt av schaktmassor

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SN - Trafikverket 2014/33386

Angreppssätt. Detta projekt är en delstudie som ingår i ett EU interreg projekt, dvs projektet EMOVE. Föreliggande delprojekt kommer att utföras parallellt med ytterligare ett delprojekt som skall genomföras inom ramen för EMOVE. Föreliggande delprojekt fokuserar på att bedöma påverkan på miljö och hälsa för olika transportsätt av schaktmassor (från infrastrukturprojekt). Projektet baseras på sammanställning av resultat från tidigare studier och undersökningar men även exponeringsbedömnignar och nya analyser beräkningar bland annat i form av livscykelanalyser. Syfte. Syftet med denna studie är att undersöka och utvärdera hur möjliga transportsätt av schaktmassor påverkar miljön och socioekonomiska aspekter. Transportsätten kommer att utgå från alternativa hanteringssätt som redovisas i ”Alternativa hanteringssätt av schaktmassor”. Fokus för denna studie kommer att vara verksamheter i Göta älvs estuarium men ska utgöra ett underlag och stöd till beslutsfattare inför generella diskussioner kring masshantering inom infrastruktursatsningar. Mål. Det finns ett behov i att bedöma olika transportsätt för hantering av stora mängder överskottsmassor på ett hållbart sätt. För detta krävs ett underlag som beskriver vilka alternativa transport- och hanteringssätt som kan ligga till grund för låga emissioner, energieffektivet och långsiktig hållbarhet. Målet med detta projekt är att ta fram underlag för bedömning och värdering för olika transportsätt baserat på miljöpåverkan och erfarenheter från experter och intressenter.

3.11 Improving renovation waste management in Sweden: The role of the demolition company

Andersson, Rickard. Mfl

Association of Researchers in Construction Management, ARCOM 2019 - Proceedings of the 35th Annual Conference

Recent directives expressed by the European commission are targeting that 70 percent of non-hazardous construction and demolition waste should be recycled compared to the current ratio of 50 percent. The common assumption is that these goals are achievable by putting pressure on the construction industry. It is however unclear how these figures can be achieved. Even though there's been a strong focus on waste management activities within the construction management literature, especially during the design and construction phases, the actual work performed by subcontractors is often missing. In particular, the role of the demolition company that is in charge of both the handling of waste on site and its distribution afterwards is overlooked. This paper aims at identifying and analysing the perceived challenges met by these companies to increase recycling. To do so, we build on institutional work which enables us to identify taken for granted institutionalized behaviour on a micro level. Drawing on qualitative research methods, we collect empirical material through semi-structured interviews with both site managers and demolition subcontractors and observation of practices on site of renovation projects in the region of Gothenburg, Sweden. The result identifies how current institutions are maintained and reproduced, preventing the development of new practices and which actors may disrupt the existing institutions and thus enable change towards more sustainable waste management practices.

3.12 Improving the recycling rate of the construction industry

Grigoriadis, K. mfl

Sustainable Construction Materials and Technologies : International Committee of the SCMT conferences

Construction and Demolition Waste (CDW) accounts for approximately 25-30% of all waste generated across Europe each year. However, Waste Framework Directive 2008/98/EC requires from all EU member states to achieve at least 70% re-use, recycling or other recovery of non-hazardous CDW by 2020. In response, the Horizon 2020 RE4 Project (REuse and REcycling of CDW materials and

structures in energy efficient pREfabricated elements for building REfurbishment and construction) consortium was set up. Its main aims are to assess the quality of various CDW fractions (e.g. mineral aggregate, timber, plastics, silt & clay), improve the quality of mineral aggregates and develop different building elements/components which contain at least 65% of CDW. Innovative building concepts will also be developed in an effort to improve recycling rates of future buildings through the use of prefabrication and modular design. The developed products and technologies will be assessed in a number of test sites by building 2-storey demonstration houses.

4 Järnväg

4.1 Ett hållbart och grönt järnvägssystem

Bustad,Tohmmy, Trafikverket

Destination 4, Ett hållbart och grönt järnvägssystem, fokuserar som nämns ovan på att minimera hela järnvägssystemets totala energi- och resursförbrukning samt dess miljöpåverkan. Avsikten är att åstadkomma ett mera attraktivt och klimattåligt transportsystem för både passagerar- och godstrafik. För att ytterligare nå målet om attraktivt transportsystem för passageraområdet har fokusområden såsom attraktivitet samt hälsa och säkerhet tillkommit. Destinationen fokuserar med andra ord på ett vitt spektrum av frågeställningar kopplat till miljö, energi, hållbarhet, cirkularitet, attraktivitet, säkerhet och hälsa mm inom hela det komplexa järnvägssystemet. Från järnvägssystemet som helhet ned till specifikt stationsanläggningar, infrastruktur och rullande materiel.

4.2 A framework to develop and evaluate circular economy readiness within the rail sector

The circular economy (CE) has been a policy initiative for supply chain looping strategies to reuse, refurbish, recycle, minimise, eliminate, share, and optimise material and energy use while maintaining firm profitability. Nevertheless, it appears there is no unified reporting framework that defines how effective an organisation's circular economy activity is. Furthermore, such a framework requires systems-wide thinking and co-ordinated action across business, government and society. Also, it appears there are no previous studies that have examined how an organisation's CE effectiveness can be developed or measured specifically based upon Systems Theory. In particular, within the context of how an organisation designs itself, its products and services, such that it can continually adapt and remain viable and sustainable in the future. If organisations were concerned enough about their own viability in relation to the products and services they sell and the impact that they have on the environment, then their business strategies and plans would include evidence to continuously improving circular economic activity. If customers and Regulators understood how effective an organisation's products and services were in having a reduced or minimised impact, or better still, had a regenerative effect on the environment then this would create visibility of CE competition and CE value against incentives. To create a CE competitive environment, the products and services that form part of that CE competition relies upon 'thinking in systems'. Systems Thinking is the ability to understand and/or design non-linear interdependencies of feedback relationships in context. For example, within a CE context, designing things for their next use, design for disassembly, maintaining the residual value of raw materials, designing products as an asset instead of a liability (to the environment) and designing products of service. As this research is still a work in progress, this paper does not aim to present a conclusive approach or methodology; rather, it presents a progressive step towards the development of a CE readiness framework within the rail sector. The longer-term aim for the outcome of the research in future will be to form the basis to enable a common platform to determine levels of CE value/competition not only within the Rail sector but wider industry.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85114221409&partnerID=40&md5=85c38b007733d8eebabc03275d401259

4.3 The feasibility of using asphalt concrete with a high percentage of recycled asphalt material in a railway trackbed layer

The use of asphalt concrete (AC) for railway trackbed layers is now well established and, in some countries, even accepted as a standard solution for high–speed or high–load lines. To date constructed track sections which incorporate AC trackbed layers use AC mixtures which contain only up to 30% of reclaimed asphalt (RA). This limit is most likely a remnant of the past when the amount of RA in AC mixtures was limited as a precaution to compensate for the lack of experience with RA. Nowadays, the trend and the aspiration for using higher percentages of RA in AC mixtures is increasing and railway

engineering should embrace this. This paper presents the results of ongoing research to this end. The first part of the paper describes a laboratory–based investigation into the required design properties of an AC mixture made of 100% of RA. The second part describes the construction and continuous assessment of a trial section on an operational mainline in the Czech Republic. The results show that it is possible to construct an AC trackbed layer with a high percentage (70%) of RA using only simple mechanization and that such a layer provides an effective formation treatment, significantly reduces the loss of track geometry, provides more uniform track support and protects the subgrade from the adverse effects of temperature changes and the ingress of rainwater. The paper concludes that an AC mixture for a railway trackbed layer should be treated as a specific type of AC mixture, with its own set of design criteria, and invites further research into the feasibility of using AC with high percentage of RA not only as a remediation technique but as a standard trackbed solution.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85096832892&doi=10.1016%2fj.trgeo.2020.100429&partnerID=40&md5=8bdb71a8dcb27bb87373c2e299f43846

4.4 Eco-friendly high-strength concrete engineered by micro crumb rubber from recycled tires and plastics for railway components

Crumb rubber concrete (CRC) is one of the new construction materials, which has been developed as a by-product from wasted rubber tires and plastics. Most previous research focuses on applications of low-strength CRC that cannot linearly predict the high-strength counterpart. This paper thus presents a study into engineering characteristics of higher-strength CRC and its benefits to the environment, as well as investigates the ability of micro crumb rubbers to enhance CRC's mechanical properties. The results revealed that replacing fine aggregate with micro rubber particles caused a reduction in mechanical properties of concrete. However, because of the micro size of rubber content and silica fume (SFC), the compressive strength of CRC achieved over 55 MPa, which will significantly benefit the advanced construction of compliant structural systems. The tensile strength of CRC was higher than plain concrete by approximately 8.74 % (splitting tensile strength) and 17.46 % (flexural strength), but it was still lower than that of SFC concrete. Moreover, CRCs also provided the ability to resist cracking of the concrete. It is found that a suitable amount of rubber particles should not bemore than 10 % of the weight for novel and sustainable high-strength CRC in railway applications. The outcome of this study will help improve the database for materials in civil constructions. The adoption of sustainable high-strength CRC in railway practices will significantly minimize wastes from used rubber tires and plastics, thus paving a robust pathway for environmental impact to societies.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85084322138&doi=10.1520%2fACEM20180058&partnerID=40&md5=34f0a58a17a627437f1fcb8b180f526c

4.5 Experimental and numerical investigations on the shear behaviour of recycled railway ballast

Ballast degradation is frequently observed under cyclic loading, and results in bearing capacity and drainage problem of ballast track. To keep the stability and safety, periodical maintenances are needed, such as cleaning and replacement, which produce a huge amount of wasted ballast. Thus, reusing the deteriorated ballast can become a considerable method for sustainable railway development and environment protection. One applications is adding the cleaned deteriorated ballast (i.e. recycled ballast) into fresh ballast. Furthermore, it is common situation that applying the mixture of fresh and deteriorated ballast during the railway operation. To study the mechanical behaviour of this mixture and find out the criterion weight proportion of the recycled ballast, a series of large direct shear tests were performed with different weight proportions (0%, 10%, 20%, 30%, 40%, and 50%) of recycled ballast mixed into fresh ballast under different normal stresses (50, 100 and 200 kPa). In addition, a numerical simulation based on discrete element method (DEM) was used to illustrate the shear strength, contact forces, coordination numbers and displacements of ballast particles. Results show that the shear strength reduction of the mixture is insignificant, when mixed with less than 30% recycled ballast. With the recycled ballast proportion increasing, the shear strength and coordination number reduce and the displacements get larger. This research provides a foundation for the application of recycled ballast, and on the other hands, adding fresh ballast can be a solution to reinforce deteriorated ballast bed.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85065703362&doi=10.1016%2fj.conbuildmat.2019.05.020&partnerID=40&md5=c3b0503adfe7e20adef2b86be9e47e22

4.6 Utilization of crushed concrete aggregate in light rail construction

As the popularity of light rail is growing, it has become apparent that there is a need to examine the possibilities of using recycled crushed concrete aggregate (CCA) in light rail construction as well. CCA has been used in Finland for road and street construction since the early nineties. Experiences have been good. In the follow-up studies of trial sections, higher values for bearing capacity were measured for the structures with CCA than for the reference structures constructed with crushed rock. The nature of the stresses in the sub-ballast layers of a light rail structure can be compared to the stresses in a road structure. Thus, it can be assumed that CCA is a suitable material to be used in the unbound layers under the ballast bed in a ballasted light rail track or under the concrete slab of a slab track -type light rail track. Experiences and research findings from Finland and other countries were collected as a literature review and light rail structure was studied on the basis of the experiences in road structure. In addition, stresses in a light rail track bed caused by train loads were estimated using a multi-layer linear elastic calculation approach. Using CCA in the ballast bed would require additional research, as the train loads in a ballasted track might cause different, more abrasive wear on the ballast material compared to the stresses in a road structure or the lower layers in a track structure.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85111944232&doi=10.32075%2f17ECSMGE-2019-0867&partnerID=40&md5=572100c46d01a7fa43ece006451e480b

4.7 Briefing: Embedding circular thinking in a major UK infrastructure project

High Speed Two Limited (HS2 Ltd) has identified that there is a strong alignment between the High Speed Two strategic goals and potential circular economy benefits and has therefore adopted a holistic approach to realising these benefits in the delivery of the UK's new high-speed rail network. This paper describes the work undertaken to date, including establishing, embedding and communicating circular economy principles, coordinating the realisation of opportunities and reporting outcomes, as well as providing lessons learnt for other infrastructure projects.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85064344378&doi=10.1680%2fjensu.17.00070&partnerID=40&md5=980e153e258c7f0add149f5961ac67b4

4.8 Steel Slag Aggregate Characteristics Evaluation as Railway Ballast

The use of recycled materials is a new tendency in the field of railway engineering. Steel slag aggregates (SSA) are one of the recycled materials derived from the steel industry. The application of SSA in ballasted railway tracks requires mechanical examination. In the present paper, the shear behavior of the ballast layer constructed by SSA and basalt aggregates was considered to assess the use of SSA as a substitution for basalt. In this regard, a series of large-direct shear tests were performed on basalt and SSA under various normal stresses. Based on the results, basalt aggregates have higher shear resistance than SSA for all normal stress. However, steel slag has sufficient shear strength as well as particle abrasion resistance. Overall, it was proven that the SSA has suitable stability against shear forces that could be applied on railway ballast.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85113207465&doi=10.1007%2f978-3-030-77234-5_37&partnerID=40&md5=5f98449b6dd34d54cc104b861932c31c

4.9 Cyclic behavior of semi-rigid recovered plastic blends in railway track substructure

Plastic deformation of granular layers in railway tracks under cyclic loading is a key factor controlling the substructure's stability. In particular, the granular subballast capping layer placed between the ballast and subgrade can undergo permanent deformations due to the moving wheel load of trains. This study was conducted to evaluate the cyclic behavior of recovered plastic (RP) blended at different percentages with construction and demolition (C&D) aggregates as railway subballast capping layer. Recycled concrete aggregate (RCA) and crushed brick (CB) were used as the parent C&D aggregates. Multistage triaxial compression tests were initially undertaken to determine the shear strength and the effect of RP inclusion on strength characteristics. The results of multistage triaxial compression tests were also used to find a link between static shear strength and cyclic deformation of the granular

recycled materials. The plastic deformability of the RP + C&D blends was also assessed through multistage cyclic triaxial tests at three confining pressures and incremental deviator stress at each confinement. The shakedown theory was employed to characterize the changes in permanent axial and radial deformations, resilient axial strain, and permanent axial strain rate. Inclusion of RP in the RP + C&D blends was found to increase the sample's deformability particularly in the secondary phase of deformation, reduced the stiffness, and most importantly increased the rate of permanent strain accumulation.

https://doi.org/10.1016/j.trgeo.2021.100514

http://www.sciencedirect.com/science/article/pii/S2214391221000039

https://trid.trb.org/view/1764401

4.10 Use of recycled rubber inclusions with granular waste for enhanced track performance

The application of recycling waste materials such as coal wash (CW), steel furnace slag (SFS), and recycled tyre products in transport infrastructure developments is an efficient way of minimising waste accumulation in stockpiles. Apart from significant economic and environmental benefits, it helps to improve the stability and longevity of infrastructure foundations. This paper presents two of the recent novel studies on (i) a synthetic energy absorbing layer (SEAL) by mixing SFS, CW and recycled rubber crumbs (RC) for railway subballast, and (ii) under sleeper pads (USPs) to increase track stability and reduce ballast degradation. The track performance incorporating SEAL with different rubber contents and USP with various stiffnesses was investigated using large-scale laboratory tests and numerical modeling. The test results and the numerical simulation indicate that the inclusion of USP acts as an energy absorber and reduces the deformation and ballast degradation; the SEAL with 10% rubber can efficiently reduce the lateral dilation and ballast breakage and increase the energy dissipation with an acceptable level of settlement.

https://doi.org/10.1016/j.treng.2021.100093

http://www.sciencedirect.com/science/article/pii/S2666691X2100049X

https://trid.trb.org/view/1876095

5 Väg – Asfalt

5.1 Towards sustainable roads: A State-of-the-art review on the use of recycling agents in recycled asphalt mixtures

The use of asphalt mixtures containing previously paved asphalt mixture from milled pavements, so-called reclaimed asphalt pavements or RAP, has been around for more than half a century. Historically, relatively low RAP contents were used, around 15% of the total mix. Recently, the use of high RAP contents has increased and now it is common to design mixtures with 30% or higher RAP contents, especially in the US. At these higher recycled contents, the characteristics of the recycled material begin to significantly affect the behaviors of the asphalt mixtures and alter the pavement performance. The use of recycled materials in asphalt mixtures at these contents may result in diminishing returns in terms of prospective performance at or beyond a certain incorporation dosage level. To overcome this barrier, recycling agents (RA) have been proposed to extend the break-even point and/or provide savings, both in terms of cost-effectiveness as well as environmental impacts. This paper is an examination of the use of RAs in recycled asphalt mixtures. There have been many reviews regarding RAs in the recent past, notably the review compiled as part of the United States National Cooperative Highway Research Program (NCHRP) Project 09–58. However, this field is evolving very quickly and there have been notable advances that require a renewed examination of the state of the art with respect to RA usage. In these intervening years, some specific advances have been made to propose novel methods for understanding the chemical nature of RAs, how RAP interacts with the virgin binder and RA, and how acceptable performance of recycled asphalt binder blends and mixtures can be achieved through dosage selection methods. However, the scientific knowledge on the selection and use of RAs in asphalt pavements is limited, and there is a need to develop robust methodologies that establish threshold criteria and performance metrics to facilitate their use on a regular basis. While there do exist some general trends with respect to RA effectiveness, the specific benefits and limitations found in individual studies vary greatly. Thus, given the current state of

knowledge, RAs should be evaluated on a material-by-material basis using asphalt mixtures designed and delivered using local practices.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85152237477&doi=10.1016%2fj.jclepro.2023.136994&partnerID=40&md5=43abe8d72d6a6894ec5ade496caa2221

5.2 Environmental impacts of road pavement rehabilitation

Road pavement generates significant environmental impacts through the production, transportation, construction, and maintenance stages. Recycling methods can be used to reduce the demand for virgin materials, but these alternatives are not environmentally benign either. Using life cycle assessment of a real case study near Chatham, Ontario, we model the trade-offs of a road rehabilitation project over a 30-year service life, subject to three scenarios. These scenarios use differing quantities of resources and blends of reclaimed asphalt pavement (RAP). Results show use of RAP with cold in-place recycling substituting virgin materials improves the environmental performance of most indicators, including climate change. These gains are only slightly diminished by the additional transportation of machinery, which we show through sensitivity analysis is likely to improve as the method becomes more commonplace. This research fills a gap in knowledge for understanding the potential improvements for pavement rehabilitation supply chains.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85152437463&doi=10.1016%2fj.trd.2023.103720&partnerID=40&md5=a8e9cb34aa20d48bfb5663f71be6c720

5.3 Evaluation of Microwave Heating for Potential Applications in Hot In-Place Recycling of Asphalt Pavement

Hot in-place recycling (HIR) has been adopted in pavement engineering because of its low financial cost and lower consumption of nonrenewable material. At present, infrared heating is the most common heating method in HIR, while microwave heating has been proposed as an alternative to it recently. This study investigated and compared the characteristics of microwave and infrared heating by laboratory experiments and numerical modeling. Laboratory tests were first conducted to determine thermal parameters of asphalt mixture and calibrate electromagnetic parameters based on numerical simulation. Two numerical models of microwave and infrared heating under field conditions were further established for analyzing the heating characteristics, including the temperature distribution, heat transfer rate, and energy consumption. The results show that infrared heating can only heat the pavement at shallow depth, while microwave heating can heat the pavement surface and the materials at greater depths to high temperatures. An increase in power was found to enhance the efficiency of microwave heating but to maybe reduce that of infrared heating. Moreover, under the same power, microwave heating needs much less time and energy than infrared heating to reach the same temperature. Microwave heating shows great potential to be applied for HIR of asphalt pavement with the increased recycling depth.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85138256464&doi=10.1177%2f03611981221086635&partnerID=40&md5=60bc61adcd6dacf1ba2ab980a3f9aa56

5.4 Recycled asphalt pavement materials in transport pavement infrastructure: Sustainability analysis & metrics

Transportation infrastructure is one of the largest consumers of natural materials. To improve the environmental quality and sustainable development of transportation infrastructure, it is important to implement sustainable strategies in pavement construction and rehabilitation. The use of recycled materials is a key element in generating sustainable pavement designs to save natural resources, reduce energy, greenhouse gas emissions, and costs. The objective of this study was to propose a methodology for assessing the environmental and economic life-cycle benefits when using recycled asphalt pavement (RAP) materials in highway projects. Previous studies on life cycle analysis (LCA) using RAP focused on the economics and/or environmental impacts during the material production process. Thus, there is a need to consider sustainability analysis at all stages of construction and rehabilitation during the performance period of pavement structures. This study addresses this need with the proposed methodology. The suggested approach could be potentially implemented in a

pavement management system (PMS) so as to introduce sustainability principles in optimizing alternative rehabilitation strategies. The methodology includes various steps for the analysis, starting with condition assessment of the existing highway, identifying alternative structural pavement designs, predicting service life, setting up alternative rehabilitation strategies, and conducting life cycle environmental and economic analysis. To demonstrate the value of the methodology, a comparative parametric study was conducted on two real case study projects representing actual field conditions for primary roads in Maryland. These case studies were used in order to quantify the economic savings and environmental benefits of using different levels of RAP in highway rehabilitation. The results of the analysis indicate that incorporating RAP in pavement rehabilitation can contribute substantially to cost savings and environmental impact reduction (e.g., greenhouse gas emission, energy, water, and hazardous waste). The benefits illustrated in this study are expected to encourage wide adoption of the proposed methodology and the use of recycled materials in highway construction and rehabilitation. The methodology is transferable where similar materials and highway construction techniques are used.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85111376153&doi=10.3390%2fsu13148071&partnerID=40&md5=2ae34cc964389a73c16d53b096dcc817

5.5 Investigating the “circular propensity” of road bio-binders: Effectiveness in hot recycling of reclaimed asphalt and recyclability potential

In pavement engineering, the use of bio-binders and reclaimed asphalt (RA) promotes the principles of sustainability and circular economy, without penalizing or even improving the performance. In this regard, this study focuses on the “circular propensity” of bio-binders obtained by partially replacing a conventional bitumen with a bio-oil generated as a residue by the wood and paper industries. Specifically, the objectives are: 1) to assess the effectiveness of bio-binders in the hot recycling of traditional RA and 2) to evaluate, in a long-term perspective, their recyclability potential. For this purpose, two severely aged binders (one “RAP” binder recovered from reclaimed asphalt and one laboratory-produced “Bio-RAP” binder) and two fresh binders (one bio-binder and one bitumen) are blended to reproduce four hot recycled binders. The mechanical behaviour and the aging susceptibility of these blends are compared to those of a control virgin bitumen. The experimental investigation includes conventional tests, rheological testing and modelling (modified CAM model) as well as chemical analysis (Fourier transform infrared spectroscopy). The main results indicate that the hot recycling of reclaimed bio-asphalt (bio-RA) may lead to mixtures less susceptible to cracking as compared to the recycling of conventional RA, as well as the use of bio-binders in the hot recycling of conventional RA may be beneficial in terms of cracking. Even though the blends with the bio-binder are characterized by a lower aging rate, the permanent deformation behaviour of all the recycled blends studied is comparable in unaged and short-term aged conditions, i.e. the circumstances under which rutting is usually a concern. Finally, the recycled blends show significantly lower aging susceptibility than the control bitumen. Overall, these results suggest that the bio-binders studied are effective in the hot recycling of RA and 100% recyclable, and their use in asphalt pavements can lead to significant technical and environmental benefits.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85078221027&doi=10.1016%2fj.jclepro.2020.120193&partnerID=40&md5=540b1fd32dad0c8916a91425724f9175

5.6 Recent Development of Recycled Asphalt Pavement (RAP) Bases Treated for Roadway Applications

Recycled asphalt pavement (RAP) has increasingly been used as a base material for highway construction as a sustainable solution. Due to the existence of asphalt, 100 % RAP typically has low strength and high potential of creep and permanent deformations. RAP can be blended with virgin aggregate, stabilized by cement and fly ash, or confined by geocell to increase its strength and reduce its creep and permanent deformations. This paper examines several recent experimental studies on treated RAP bases (blended RAP aggregate, cement and fly ash-stabilized RAP, and geocell-confined RAP) and discusses the key findings from these studies including the proportion of RAP to virgin aggregate, type and percent of stabilizing agent, strength, modulus, and creep deformation of treated RAP under static loading, and permanent deformation of treated RAP under cyclic loading.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85018193063&doi=10.1007%2fs40515-015-0018-7&partnerID=40&md5=a978565fc46a5a5e252bf2e15f47495f

5.7 Use of geosynthetics to stabilize recycled aggregates in roadway construction

During the re-construction of existing roads, including highways and railways, a large amount of concrete and asphalt pavements and ballast are removed and disposed. For sustainable use of these materials, they have been increasingly recycled as aggregates for the construction of roadways. Due to the existence of asphalt, cement, and fines, the mechanical properties (mainly strength and stiffness) of recycled aggregates decrease. They may also have long-term durability problems, such as the breakage and abrasion of crushed concrete and creep of recycled asphalt pavement. Geosynthetics (including geotextile, geogrid, and geocell) have been used to improve the mechanical properties and long-term durability of recycled aggregates. This paper reviews recent research work on the use of geosynthetics to stabilize recycled aggregates in roadway construction and summarizes the main research findings including the permanent, resilient, and creep deformations, stress distribution, strength, and modulus of geosynthetic-reinforced recycled aggregates.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-84887388243&doi=10.1061%2f9780784412688.057&partnerID=40&md5=1c1e5e4e4314d1edb1c9a709218ebd5f

5.8 Guideline for RA assessment, mix and pavement design as well as maintenance needs for cold recycled asphalt bases for flexible pavements

Compared to the usually applied hot-mix asphalt pavements, the use of cold recycled asphalt base layers (CRAB) in flexible pavements is less common in road construction. However, several European countries have a long experience in these materials, which are usually composed of high contents of reclaimed asphalt (> 75 %), bitumen emulsion and cement. The analysis of national specification documents as well as of existing pavements with CRAB identified a wide range of mix and pavement designs applied but also commons in the used design methods. The existing pavements with CRAB perform very similar to asphalt pavements composed of hot-mixed asphalt base layers even at high traffic loading. At the same time, the production of cold recycled materials (CRM) will result in a reduction of at least 40 % of environmental impact factors, including global warming potential (-42 % of CO_2 -eq.), acidification of freshwater (-51 % of P-eq.), eutrophication of freshwater (-58 % of P-eq.) or fossil energy resources (-61 %). The assessment of 17 existing CRAB pavements allows the conclusion, that these benefits are not reduced by higher maintenance demands of the pavements, if feasible mix and pavement design principles are followed.

https://www.cedr.eu/docs/view/622f6ef3df972-en

https://trid.trb.org/view/1928839

5.9 Laboratory Assessment of Recycled Asphalt Pavement as Roadway Embankment Material

Rehabilitation or reconstruction of roadways produces a large amount of recycled asphalt pavement (RAP). Typically, RAP is often reused as a part of hot mix asphalt. However, the in situ utilization of RAP offers advantages such as reduction of construction cost and expedition of construction process. On the other hand, including considerable percentages of RAP as a fill material in the embankment of pavement structures may increase the risk of settlement. In this study the behavior of RAP samples from five sources in Illinois, two conventional soils, and a lab-produced mixture of soil and RAP is investigated. Gradations, moisture–density relationships, dynamic triaxial, direct shear and one-dimensional consolidation tests at various conditions were performed. Results show that an increase in the temperature of RAP during compaction significantly increased the maximum dry density (MDD). Also, the mixed sample of soil and RAP results in the highest standard Proctor MDD. Increase in temperature significantly increased the compression of RAP. Achieving good settlement performance for RAP is feasible if the RAP samples are screened to pass 1.5-in. sieve and if the compaction of the RAP samples reaches 100% of standard MDD. Based on the dynamic triaxial testing, deformation of RAP does not stabilize as soils do. To mitigate this issue, it is recommended not to use RAP within the influence zone of traffic load, specifically the top 5 ft of an embankment in a rigid pavement structure and within the top 8 ft of an embankment in a flexible pavement structure.

https://doi.org/10.1177/03611981221151025

https://trid.trb.org/view/2114279

6 Betong

6.1 Valorization of Dredged Sediments and Recycled Concrete Aggregates in Road Subgrade Construction

Large quantities of dredged sediments and recycled concrete materials are generated every year all over the world. The disposal of these large quantities in landfills represents serious environmental problems. Furthermore, high-quality raw materials for construction are depleting, and their use cannot be sustained. The valorization of dredged sediments and recycled concrete materials as alternative construction materials has the potential to reduce the impact of these two issues. In this context, this study aims at investigating the feasibility of using dredged sediments and recycled concrete aggregates as alternative raw material for road subgrade construction. Various mix designs were prepared using dredged sediments and recycled concrete aggregates. The mixes were then treated with quicklime and road binder as specified in the French soil treatment guide. Their physical, mechanical, and geotechnical properties confirmed the feasibility of using recycled concrete aggregates and dredged sediments up to a certain percentage in road subgrade construction. Moreover, they showed that the mixes containing 20% of dredged sediments met road subgrade minimum physical and mechanical properties, such as immediate bearing capacity, unconfined compression strength, indirect tensile strength greater, and UCSI/UCS60 ratio. Finally, leaching tests were conducted to ensure the environmental safety of the various mixes. The results showed that the mixes met the thresholds for their use in road subgrade construction. The feasibility of using dredged sediments and recycled concrete aggregates in foundations and base layers will be studied in future projects.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85151733633&doi=10.3390%2fbuildings13030646&partnerID=40&md5=f22dd0b3a33e9ad93de3138572867e67

6.2 The impact of recycled concrete aggregate on the stiffness, fatigue, and low-temperature performance of asphalt mixtures for road construction

The need for road (re)construction materials is constantly growing. At the same time, there is a limited quantity of new, high-quality materials available and a buildup of secondary/recycled construction materials. One possible solution may be the use of recycled concrete aggregate (RCA) in asphalt mixtures instead of natural aggregate (NA), which also promotes economic and environmental sustainability. The potential use of fine and coarse RCA in road asphalt mixtures is analyzed in this work. Nine asphalt mixtures were tested for base course layers, where RCA was used as a NA substitute. The impact of the quantity of RCA (up to 45% by mass) on the resulting physical and mechanical properties of asphalt mixtures was investigated, and consequently compared with the properties of a reference control mixture produced with NA only. Results reveal that the addition of RCA requires higher bitumen in comparison to the control mixture (up to 1%). Consequently, mixtures with RCA had 15-20% lower stiffness and up to 26% higher critical fatigue strain value (ε6). Although RCA mixtures contained more bitumen, their low-temperature resistance was slightly inferior compared with the control mixture (failure temperatures were up to 4.3 °C higher). In conclusion, asphalt mixtures with up to 45% RCA can be used without substantially reducing performance.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85085642008&doi=10.3390%2fSU12103949&partnerID=40&md5=8a3516fa32a3922f4935121fefd9a534

6.3 Sustainability of Concrete as A Civil Engineering Material

With increasing concern about the environment, energy consumption, climate change, and depletion of natural resources, the importance of sustainability has become mainstream among engineering and scientific communities. Concrete infrastructure is superbly durable and comes with a myriad of benefits. Yet, the production of concrete is energy intensive and represents a substantial portion of air pollution. Largely due to cement manufacturing, concrete represents 7% of greenhouse gas emissions globally and 1% in the United States. Focusing on sector-specific emissions in the United States., this paper outlines the environmental concerns of concrete production and discusses the forefront of

research in reducing these effects including innovations in cement manufacturing, alternative clinker technologies, and carbon capture use and storage. Also discussed are various approaches and efforts in concrete recycling and incorporation of industrial wastes and supplementary cementitious materials into concrete. Finally, this study reviews the role of civil engineering design at various scales in the sustainability of concrete infrastructure.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85135153575&doi=10.4186%2fej.2022.26.7.69&partnerID=40&md5=74925f5f6477c223272ff2882b06bed7

6.4 The potential use of lightweight cellular concrete in pavement application: a review

Protecting the pavement subgrade to increase the service life of road pavements is an aspect currently being explored. Several alternative pavement subbase materials are being considered, including Lightweight Cellular Concrete (LCC). Due to its lower weight, LCC incorporating industrial by-product, making it sustainable, and ease of use amongst other benefits, is seen as a potential candidate. This paper reports reviewing the potential application of LCC within the pavement structure with a specific application as a subbase. It examines the various properties such as modulus of elasticity, compressive and tensile strength, Water absorption, and freeze-thaw resistance necessary for pavement application. It also assesses its use in the field in Canada considering the design methods utilized. Some limitations and gaps for LCC application in pavements are also established and recommendations on how to further its use and performance. This review concludes that LCC possesses potential as a pavement subbase alternative; however, other mechanical properties like LCC's fatigue life is essential. A comparative field study is also recommended to monitor actual performance and various factors on performance.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85098746127&doi=10.1007%2fs42947-020-6003-8&partnerID=40&md5=0e4c27836b0dae03c1b3a9fcb178499a

6.5 Influence of recycled concrete aggregates from different sources in hot mix asphalt design

The waste generated by the construction industry generally has an undesired negative impact on both human and animal life as well as the environment. Among these wastes, recycled concrete aggregate (RCA), due to its good residual physical, mechanical, mineralogical, and chemical properties, has attracted promising potential for re-use and incorporation in the construction of new infrastructural elements. These infrastructure applications include construction of sidewalks, curb and gutters, subbase/base layers, and/or as a partial replacement of natural aggregates (NA) in the production of hot mix asphalt (HMA) mixtures. In this laboratory study, experimental research work was conducted to evaluate the influence of RCA on the mechanical properties and performance of RCA modified HMA mixtures against a control HMA mixture without any RCA. RCAs were obtained from two different concrete sources, namely: (a) one from the demolition of a building (RCAB), and (b) another one from the rehabilitation of a Portland cement concrete pavement (RCAP). Both NA and RCA were characterized taking into account physical and mechanical properties. HMA mixtures were produced using the Marshall mix-design method by replacing 0.0% (control), 15%, 30%, and 45%, respectively, of the coarse NA fraction with RCA. Thereafter, laboratory testing (i.e., Scanning Electron Microscopy [SEM], resilient modulus, indirect tensile strength, etc.) including material property characterization and performance evaluation were conducted on HMA samples. Overall, the laboratory test results showed that the RCA modified mixtures exhibited a similar behavior to conventional HMA mixtures, but with greater environmental benefits and potential cost savings through the recycling and reuse of waste concrete aggregates. However, it was observed that the laboratory performance of RCA modified mixtures is strongly dependent on the RCA source and dosage, with RCAP exhibiting superior performance over RCAB. HMA mixtures produced with RCA provided higher optimum asphalt-binder content (OAC) than that of mixes with NA.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85089883503&doi=10.1016%2fj.conbuildmat.2020.120427&partnerID=40&md5=25270dc59fc516592f717bcbd2c406ad

6.6 Constructivate arbetspaket 3 : Återvinning av rivningsavfall som ballast i betong

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Bygg- och rivningsavfall utgör en av de största avfallsströmmarna i Sverige, samtidigt som den återvinning som sker sträcker sig till tillämpningar med relativt låga kvalitetskrav (downcycling). Sannolikt finns potential till att återanvända rivningsavfall i tillämpningar av högre status, till exempel i ny betong eller i delar av vägkropp där kvalitetskraven är högre.Syftet med denna rapport är att undersöka vilka regler och kvalitetskrav som finns för återvinning av den mineraliska materialfraktionen i rivningsavfall. Fokus har varit på hur denna fraktion måste vara beskaffad för att klara kvalitetskrav som ballast till vägbyggnad och ny betong.För vägbyggnad finns ett klassificeringssystem i den europeiska standarden SS-EN 13242 (Ballast för obundna och hydrauliskt bundna material för användning i anläggningsarbeten och vägbyggen) och i Trafikverkets kravdokument TDOK 2013:0532 (Alternativa material för vägkonstruktioner). Kvalitetsklassningen sker på basis av fraktionens sammansättning med avseende på ingående materialslag, där Klass 1 (högsta klassen) i princip bara innehåller krossad betong, murverk och obunden sten, medan det i lägre klasser (i ordningen 2, 3 och 4) accepteras stigande inslag av kvalitetssänkande material (tex metaller, plast, trä, lättviktsbetong). För viss klass måste dessutom tekniska krav uppfyllas, uttryckta i termer av motstånd mot nötning eller tryckhållfasthet. TDOK 2013:0532 anger vidare vilken kvalitetsklass som krävs för olika delar av vägkropp: Klass 1 eller 2 för Förstärkningslager till belagda vägar och Bärlager till belagda vägar, minst Klass 3 för Skyddslager till belagda vägar, samt minst Klass 4 för Underbyggnad och övriga fyllningar.För användning som betongballast krävs enligt SS 137003, vilket är den svenska tillämpningen till den europeiska betongstandarden SS-EN 206, att den återvunna ballasten karaktäriseras och klassificeras. Klassificeringen sker helt enligt standarden för betongballast (SS-EN 12620) och bygger likt systemet för användning som vägballast på innehåll och halter av ren betong och andra materialslag i den återvunna ballasten. Här är klasserna i nuläget endast två: Typ A och Typ B, där den förra är den högre (och renare) klassen. Eftersom SS-EN 12620 är harmoniserad ska återvunnen ballast till och med CE-märkas. CE-märkningen sker på samma sätt och med samma system som för primär/jungfrulig ballast, med några skillnader så som att analys av sammansättning med avseende på materialslag måste göras, samt att dokumentation och spårbarhet till rivningsprojekt måste finnas i kvalitetssystemet.Det står helt klart att hur användbar den mineraliska fraktionen från bygg- och rivningsavfall är beror på dess renhet, dvs. hur väl man lyckats hålla isär olika avfallsfraktioner. Generellt innehåller inte den krossade betongen i sig ämnen som kan vara skadliga för människa eller miljö; dessa finns snarare i andra materialslag som kan finnas ihop med betong i rivningsavfall. Under vissa perioder har man vid byggande av hus använt material som senare visat sig orsaka hälsoproblem och förbjudits. Exempel på sådana är ”blåbetong” (lättbetong baserad på uranrik alunskiffer) och byggprodukter med asbestcement och PCB-haltiga massor. Förekomst av dessa material i en byggnad som ska rivas måste inventeras och saneras och/eller hanteras på ett säkert sätt. Gynnsamt är förstås om man redan i rivningsskedet har kunnat separera de olika komponenterna, men även ett relativt blandat avfall kan separeras och sorteras mer eller mindre effektivt i efterhand. Moderna återvinningsanläggningar använder olika tekniker för att få ut rena(re) materialfraktioner från blandat avfall. Ofta involverar dessa tekniker flera steg av krossning, torr- och våtsållning, siktning, tvättning med högtrycksvatten och pressning av slam till kaka, i vilken oftast eventuella lakbara ämnen ansamlas.Tekniskt och miljömässigt är det fullt möjligt att återvinna rivningsavfall som ballast i ny betong och vägbyggnad, men idag sker detta alltså i mycket liten eller tom obefintlig utsträckning. Ett antal åtgärder med potential påverka i riktning att sådan återvinning ökar är:• Ta fram nationella End-of-Waste-kriterier för rivningsavfall, till exempel enligt brittisk modell. Ökar tydlighet för alla aktörer och minskar osäkerhet i tillståndsprövningen.• Gör livscykelperspektivet till ett starkt kriterium i offentlig upphandling, det vill säga att man får bonuspoäng utifrån detta samtidigt som det naturligtvis inte styr helt. Dessutom måste en LCA-bedömning ta hänsyn inte bara till CO2-ekvivalenter utan också andra miljöparametrar.• Sprid och förankra bäst praxis till kommunerna/beställarna, till exempel kring vilka sekundära material som enligt forskning och beprövad erfarenhet kan användas på vilket sätt och hur, så att krav kan ställas i upphandlingar.• Sprid kunskap och sök påverka Naturvårdsverket vad gäller riktlinjerna (och handboken) som stöd till kommuner och andra tillsynsmyndigheter, att krav bör ställas på lakbarhet och biotillgänglighet vad gäller olika ämnen, snarare än totalhalter (som kan vara hårt bundna och därmed inerta).• Sortering för högre teknisk funktion. Om avfallsfraktionerna hålls isär och så rena som möjligt, så ökar möjlighet för återvinning avsevärt (dvs. recycling, inte downcycling), vad gäller såväl teknisk prestanda som minskad risk för miljö och människa.

6.7 RE:Concrete- Study on Concrete Recycling in Sweden

http://hb.diva-portal.org/smash/get/diva2:1184916/FULLTEXT01.pdf

http://urn.kb.se/resolve?urn=urn:nbn:se:hb:diva-13710

Improving the mechanical properties of cold rolled asphalt containing cement utilising by product material

Reduction of hot asphalt mixtures for the usage and development of sustainable supplementary Cold Asphalt Mixtures (CAM) for the construction of road and highway surface layers is a hot subject for researchers around the world. This will cover many advantages in terms of: environment impact, cost effectiveness and energy saving.The aim of this study is to enhance the properties of a gap graded Cold Rolled Asphalt (CRA) containing cement as filler by addition of a by-product material as an activator. Ordinary Portland cement was added to the cold rolled asphalt as a replacement for the conventional mineral filler (0-0100%), while a by-product material represents Liverpool John Moores University Additive (LJMUA) was added to the whole mix in the range from 0 to 3% by total mass of aggregate. Laboratory tests included stiffness modulus and uniaxial creep test as indicators to the mechanical properties.The study concluded that there is a considerable improvement in the mechanical properties from the addition of LJMUA to the CRA containing cement especially for the early life stiffness modulus that is the main disadvantage of the cold mixtures.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-84956535787&doi=10.1007%2f978-94-007-7790-3_59&partnerID=40&md5=98682a5e74c10f894eabda4259fdeec0

6.8 Lateral Cyclic Response of RC Bridge Piers Made of Recycled Concrete: Experimental Study

Using recycled coarse aggregate (RCA) in construction reduces the negative environmental impacts that are associated with new concrete production. However, few studies have investigated the structural performance of bridge piers made of recycled aggregate concrete (RAC), which utilizes RCA as coarse aggregate. This paper experimentally investigated the seismic performance of RAC bridge piers. Here, three 1/3-scaled bridge piers having three levels of RCA replacement ratios (0%, 50%, and 100%) were tested. The piers represented a real bridge pier located in Vancouver, British Columbia, Canada. Their seismic performances were evaluated using a quasi-static cyclic loading protocol in the form of hysteresis behavior, strain response, moment–curvature response, energy dissipation, residual deformation, ductility measures, plastic hinge length, and failure modes. The results showed that the RAC piers had similar hysteresis and strain response behavior when compared to the conventional concrete specimen. The ductility measures for the three specimens were very close in terms of curvature and displacement ductility. Moreover, RAC specimens had slightly larger plastic hinge length, experiencing more cracks compared to the control specimen. These findings highlighted the feasibility of using RCA as a replacement of coarse aggregate in bridge piers in seismic regions.

https://doi.org/10.1061/(ASCE)BE.1943-5592.0001703

https://trid.trb.org/view/1837617

6.9 Numerical study using stiffness parameters on the nonlinear behavior of RCA pavements under heavy traffic loads

The use of the recycled concrete aggregates (RCA) obtained from construction and demolition wastes not only reduces the demand for natural aggregate, which ultimately leads to economical and eco-friendly designs, but also improves the long-term performance of a conventional flexible pavement. This study aims to investigate the effects of using 100 % RCA in the pavement subbase and base courses on the mechanical behavior of the flexible pavement. This study is divided into two stages, i.e., a laboratory study characterizing the properties of RCA and a numerical analysis evaluating the long-term performance of RCA under heavy traffic load conditions. In the laboratory study, along with the determination of the classical geotechnical properties of base and subbase samples, the stiffness properties of the samples were obtained by applying the resilient modulus and permanent deformation tests. Then, by comparing the results of the three different constitutive models, the result of the more appropriate model was selected. In the second stage, the plastic deformation (rutting) of the pavement courses and the maximum value of deflection when subjected to multiple wheel loads were determined

using a 3D nonlinear numerical method. Based on the experimental results, RCA demonstrated higher resilient modulus and lower plastic deformation compared to that of conventional base and subbase materials. Regarding the long-term behavior, the permanent strain rate of the samples was reduced at an approximately constant level during the first load cycles. Additionally, the numerical analysis results indicated that the mechanical performance and rutting values of the base and subbase courses constructed using 100 % RCA met the specified requirements.

https://doi.org/10.1016/j.trgeo.2021.100582

http://www.sciencedirect.com/science/article/pii/S2214391221000726

https://trid.trb.org/view/1852332

6.10 Performance Evaluation of Porous Asphalt Mixture Containing Recycled Concrete Aggregate

Concrete is one of the most widely used building materials, which creates a large amount of debris during demolition and/or reconstruction of infrastructure facilities (1). The recent U.S. Environmental Protection Agency statistics show that concrete accounted for 67.5 percent of the 600 million tons of construction and demolition debris in the U.S. in 2018, and 74.3 percent of the concrete debris was reused as aggregate (2). The recycled concrete aggregate (RCA) from construction and demolition waste helps to reduce the environmental impact and improve the sustainability of infrastructures by diminishing the waste sent to landfill areas, reducing the need for aggregate mining from natural resources, and eliminating the carbon dioxide (CO_2) emission that would be released during portland cement production (3). Pavement is one major consumer of aggregates because of the vast area of pavement networks and the high proportions of aggregates in all pavement structural courses. Promoting the use of RCA in pavements is one major approach to achieve sustainability and environmental protection goals. Currently, most RCA use in pavement projects is limited to the base and subbase courses due to the lower quality of RCA in comparison to virgin aggregates and the less strict specifications for aggregates in the base and subbase courses. The use of RCA in the upper course, primarily dense-graded hot mix asphalt, is still limited due to the concern that RCA may significantly impact the performance of hot mix asphalt in terms of moisture susceptibility, tensile strength, and volumetric properties (4, 5). Meanwhile, porous asphalt mixture, which features a high air-void content and high permeability, has gained significant attention in recent years in the pavement industry due to its contributions to storm water runoff volume control and quality improvement, traffic noise reduction, driving safety enhancement, and other environmental and safety-related benefits (6, 7). The high porosity of porous asphalt mixture limits its applications to scenarios where either it is not treated as a structural course or the traffic volume, load, or speed is low (e.g., shoulder, parking lot, low-volume roads). These scenarios have less strict requirements on asphalt mixtures, so can be appropriate for the use of RCA in asphalt mixtures. Currently, only a very limited number of studies have explored the utilization of RCA in porous asphalt mixtures (8). There is a need to further investigate the feasibility and method of incorporating RCA in porous asphalt mixture. The main objective of this proposed project is to investigate appropriate methods to incorporate RCA in porous asphalt mixture, evaluate the performance of porous asphalt mixture with RCA and other necessary additive, and provide recommendations on test procedures and mixture design. Specifically, the following tasks are planned: (a)Perform a comprehensive literature review of RCA characteristics, porous asphalt mixture design and performance, and the use of RCA in asphalt mixtures; (b) Develop and execute a laboratory experimental plan to design and evaluate porous asphalt mixtures containing RCA and other necessary additives; and (c) Investigate the mechanism of RCA impact on porous asphalt mixture performance and recommend test and design procedures/guidelines for porous asphalt mixtures containing RCA.

https://ctech.cee.cornell.edu/research/project-descriptions/

https://trid.trb.org/view/1868771

6.11 Sustainable Materials: A Review of Recycled Concrete Aggregate Utilization as Pavement Material

In this paper, a comprehensive literature review was conducted on the utilization of recycled concrete aggregate (RCA), which is the dominant construction and demolition waste material, in base and

subbase layers and its comparison with natural aggregate (NA). The effects of crushing on the particles as a result of the compaction on the resilient modulus, permanent deformation, and California Bearing Ratio are analyzed. The paper also contains the NA consumption and waste disposal policies of different countries, RCA standards, and the environmental-economic reasons for its use. This literature review mainly focuses on pavement layers as this is the main application of RCA in the use of recycled materials. Developing integrated construction and demolition waste management will help achieve the primary goal of preventing and reducing the generation of these wastes, both locally and globally. In this way, not only is the main purpose of preventing the increase in the production of construction and demolition waste achieved, but also the reuse and recycling of the waste materials produced are encouraged. Results show that RCA has equivalent or better performance than virgin aggregate for almost any application with proper care and process control, and can be used in unbound pavement layers or other applications requiring compaction. But it is always recommended that its mechanical properties and durability performance be evaluated with full-scale tests before use. The information provided will be useful for contractors and engineers to evaluate alternative solutions and to explore the rational use of such sustainable materials in applications.

https://doi.org/10.1177/03611981211052026

https://trid.trb.org/view/1889032

7 Gummi och plast

7.1 Environmental Performance of Road Asphalts Modified with End-of-Life Hard Plastics and Graphene: Strategies for Improving Sustainability

Road construction takes a heavy toll on the environment. Therefore, innovative strategies to improve the environmental performances of this sector are needed, and the use of recycled materials (e.g., plastic) has been recently pursued to achieve this goal. The present work aims to (i) assess the environmental benefits deriving from the use of recycled hard plastics in combination with graphene to generate a new bitumen modifier and related asphalt mixture (AM) formulations (ii) to compare the performance of the bitumen modified using this new modifier with the bitumen modified using a traditional polymer (Styrene-Butadiene-Styrene, SBS) and the non-modified bitumen. A detailed Life Cycle Assessment (LCA) study was performed according to a cradle-to-cradle approach. Different scenarios were compared, including the variability of the pavement's layers thickness and the amount of reclaimed asphalt pavement during the road maintenance cycles. The results demonstrated that the addition of the innovative modifier enhanced the structural performance of AMs, which turns into pavement extended durability, reduced maintenance cycles as well as into reduction in raw material use. The innovative asphalt modifier also creates a synergistic effect by offering a valuable alternative to hard plastic incineration by using it as a secondary raw material. This analysis allowed us to indicate the new-modified AM as the solution with the least environmental burden in all impact categories, suggesting its significant role in implementing new strategies to improve the environmental sustainability of road pavements.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85140959989&doi=10.3390%2fpr10102151&partnerID=40&md5=daba8d1389e24d504127b75971b17207

7.2 Demonstration Project for Ground Tire Rubber and Post-Consumer Recycled Plastic-Modified Asphalt Mixtures

Research has demonstrated that asphalt pavements can be a strategic destination for some of the major streams of waste materials around the globe, such as scrap tires and plastics. Ground tire rubber (GTR) from scrap tires has been used in asphalt pavements since the 1960s but has yet to approach its full potential in relation to market adoption. The heightened restrictions imposed by China in relation to waste stream contamination in 2018 have catalyzed research on incorporating post-consumer recycled (PCR) plastics into asphalt pavements. A field demonstration project was carried out in Columbia, MO to evaluate modern recycled plastic and GTR additives in an asphalt pavement overlay. The demonstration focused on dry-process modification, which requires minimal alterations to an

existing asphalt plant and allows a higher amount of recyclates to be utilized. The project was also designed to assist in the Missouri Department of Transportation's early roll-out of balanced mix design asphalt design and quality assurance specifications. The results of the study indicated the viability of dryprocess GTR and PCR plastic additives used with neat (unmodified) asphalt binder as an alternative to binders modified with virgin polymers, chemical treatments, or both, in a wet process. The results of the study also suggest the viability of hybrid wet polymer-modified binder with dry-process PCR plastic as a greener alternative to binders modified with virgin polymers, chemical treatments, or both. Future studies will be needed to examine additional PCR plastic streams, especially mixed polymer streams.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85135577781&doi=10.1177%2f03611981221078844&partnerID=40&md5=68c51f2844f378e6738b40fe2bbac61d

7.3 Pyrolysis of polyolefin plastic waste and potential applications in asphalt road construction: A technical review

Pressures on the current plastic waste management infrastructure has made the growth of new sustainable recycling capacities crucial. Pyrolysis is an emerging thermochemical technology that may be utilised at a large scale to aid in reaching the EU 2030 targets for plastic waste. Plastic valorisation via this process could gain increased competitiveness with conventional methods through the use of concepts such as 'Design for Recycling', identifying further marketable applications for pyrolysis end co-products. This paper presents a review on the pyrolysis of the most abundant plastic waste polyolefins, low-density polyethylene (LDPE), high-density polyethylene (HDPE) and polypropylene (PP), with a focus on the heavy wax products. A sizeable research gap in its known applications outside of the petrochemical and chemical feedstock industries was identified. Furthermore, its potential use in the hot mix asphalt (HMA) layers of flexible roads as an alternative binder material and aggregate is discussed. A plastic-derived bitumen modifier could be a viable solution to the current limitations associated with plastic bitumen modifiers (PMB), while producing asphalt with enhanced rheological properties and failure resistances. Consequently, future trends in research may include obtaining a full understanding of the capacity for pyrolysis products from waste polyolefins in bitumen modification. The key relationships between pyrolysis process parameters and the subsequent product properties, modification mechanisms and binder performance may also be explored. This application pairing process for pyrolysis products from plastic wastes may also be more extensively adopted in sustainable infrastructure, as well as other industries.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85124569735&doi=10.1016%2fj.resconrec.2022.106213&partnerID=40&md5=ba132f2a91325541db6fca2de6c51302

7.4 Harmless treatment and environmentally friendly application of waste tires—TPCB/TPO composite-modified bitumen

Waste tires are produced in large quantities and cause serious pollution. Moreover, it is challenging to dispose of waste tires safely. Pyrolysis treatment is an economic, environmentally friendly, and high-recovery-efficiency solution, but the recycling applications of pyrolysis products, such as pyrolysis carbon black (TPCB) and pyrolysis oil (TPO), have not been widely studied. In this study, TPO and TPCB were applied to composite-modify 70# base bitumen. The modification mechanism of TPO/TPCB-modified bitumen (TPO/TPCB-MB) was studied by Fourier transform infrared spectrometry (FTIR), gel-permeation chromatography (GPC), X-Ray diffraction (XRD), and scanning electron microscopy (SEM). The physical performance and rheological performance of the bitumen with and without TPO/TPCB were investigated to determine the design and preparation parameters of TPO/TPCB-MB and investigate TPO/TPCB's effects on the technical performance of bitumen. In addition, the road performance of TPO/TPCB-MB concrete was extensively studied. In the results, no large agglomeration phenomenon was observed between the TPCB particles. Furthermore, the

molecular weight of TPO was much lower than that of 70# bitumen, indicating that TPO can increase the light components of bitumen. TPCB and TPO mixed with the bitumen in a physical manner, and the multi-layer spacing of TPCB remained basically unchanged. The TPO/TPCB was also shown to have good thermal and structural stability. TPO and TPCB, moreover, provided component balance and powder hardening effects in the TPO/TPCB-MB. No significant difference was observed between the technical performance of the 70# bitumen and the 0.9% TPO + 15% TPCB-MB. The water stability, low-temperature, and anti-fatigue performance of the TPO/TPCB-MB mixture was significantly better than that of the 70# bituminous mixture. Meanwhile, the high-temperature performance showed no obvious difference. Therefore, TPO was found to balance TPCB's oppositive effect on the performance of bitumen and its mixture. The composite modification of bitumen with TPCB and TPO thus represents a harmless treatment and alternative use for waste tires.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85124581620&doi=10.1016%2fj.conbuildmat.2022.126785&partnerID=40&md5=dfb9cb5d73f5d6bf73b9607cc2f2eb3b

7.5 Plastic Waste for Sustainable Asphalt Roads

Plastics polymer products are ubiquitous in modern society. While plastics materials are typically durable, the most common uses are short-term, such as packaging. Vast and versatile use of plastics products has led to a major environmental problem: a massive accumulation of waste plastics worldwide. Waste plastics are typically mixed and varied in terms of quality and type of plastics. Waste plastics are most commonly disposed of and landfilled. The purpose of this chapter is to provide a perspective on the environmental impacts of asphalt mixtures with recycled plastics (RPs) from the viewpoint of environmental product declaration (EPD) development and implementation. To achieve the stated objective, this study provided an overview of the current state of EPDs and their informed uses: as a communication tool, procurement aid, and a data source. Key considerations for accurate and informed life cycle assessment for asphalt mixtures with RPs were outlined for the wet and dry process of RPs incorporation.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85129824153&doi=10.1016%2fB978-0-323-85789-5.00015-0&partnerID=40&md5=03c500de60e021715ac93e839aa91e16

7.6 New perspectives on recycling waste glass in manufacturing concrete for sustainable civil infrastructure

While a large amount of waste glass is annually produced worldwide, a limited percentage of waste glass is recycled. Recycling glass in concrete has shown great promise in solid waste management because there is a high volume of concrete in civil infrastructure. However, a consensus on the effects of waste glass in concrete has not been achieved. Some researchers reported that the use of waste glass improved the properties of concrete, but some researchers reported opposite results. The inconsistent results of the effect of waste glass hinder the acceptance of glass in producing concrete. This review aims to clarify the debates and attempts to elucidate the opposite viewpoints. To this end, this paper reviews different results reported by different research groups and proposes new perspectives based on analyzing underlying mechanisms, considering different types of waste glass, including soda-lime, electric, lead, and borosilicate glass. The reviewed contents include the fresh properties, compressive strength, durability, thermal properties, electrical properties, and microstructure of concrete. This review is expected to advance the knowledge of recycling glass in producing concrete, point out future research needs, and facilitate wider adoption of waste glass concrete in developing sustainable and durable infrastructure.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85084952565&doi=10.1016%2fj.conbuildmat.2020.119579&partnerID=40&md5=bb53983b5bb65f156af76cf9e05a4d73

7.7 Crumb rubber as a sustainable aggregate in chip seal pavement

The U.S. companies need to mine billions of tons of raw natural aggregates each year. In the same time, billions of scrap tires are going to landfills every year which makes the replacement of using natural aggregate with recycled and sustainable one is more beneficial to both industry and environment. This paper presents an extensive study on the performance of the chip seal pavement surfaces in terms of aggregate retention and performance. This study introduces a new eco-friendly chip seal by implementing the crumb rubber made of recycled tires as aggregates for such surface dressing. Twenty four specimens of chip seal were prepared and tested under three tests investigating the aggregate retention. The tests included the standard Vialit test, modified Vialit test, and sand patch test. Two types of emulsions, two types of binders, and three types of aggregates including the crumb rubber were examined in the tested specimens. This study revealed that the crumb rubbers from recycled tires would be used in the chip seal as aggregates but it is preferable to be used in conjunction with the conventional aggregates. The crumb rubber showed a remarkable performance in aggregate retention. This performance was mainly because of the low weight of the crumb rubber and its rough surface, which increased holding the crumb rubber into the asphalt emulsion or binder. In addition, crumb rubber as a partial or total replacement for the mineral aggregate was successfully implemented in the field using the traditional procedure and equipment.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85060330577&doi=10.1007%2f978-981-10-6713-6_39&partnerID=40&md5=917dc72f76b601c4b8354ddf2897a9cb

7.8 Airfield and Highway Pavements 2017: Testing and Characterization of Bound and Unbound Pavement Materials - Proceedings of the International Conference on Highway Pavements and Airfield Technology 2017

Sustainable development has become a major focus for engineers and planners as part of collective efforts in developing and integrating environmental-friendly solutions for material recycling and waste management into design and construction of civil engineering infrastructure. Significant growth in automobile manufacturing and increasing rubber tire production along with the growing concerns for protecting the environment and preserving natural resources have led the efforts in applying recycled tire particles in concrete, as environmental-friendly and cost-effective solution, to minimize the ecological footprint of such waste. Previous research has shown that introduction of rubber tire particles, as partial replacement for fine and coarse aggregates, reduces the brittleness of the concrete and provides more flexible aggregate bonding which ultimately improves the dynamic resistance of concrete. In this experimental study, various percentages of fine and coarse aggregates are replaced with fine and coarse rubber particles, respectively. The compressive and tensile strength characteristic are studied and investigated to propose a Quality Management Plan for rubberized tire applications in highway and airfield pavements. In this regard, as part of the Quality Assurance initiative, relevant quality standards for rubber-concrete mix designs and testing processes are identified to evaluate the specimens' conformance. Moreover, through acquisition and analysis of the experimental data, this paper studies the results and identifies areas of improvement to eliminate the causes for unsatisfactory performance for Quality Control purposes. It applies the Project Management Body of Knowledge (PMBOK) Quality Management and Controls Tools to achieve these objectives.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85042786063&doi=10.1061%2f9780784480939.024&partnerID=40&md5=a38b20ce2e02ae0a9e8f91a1b0d7f88e

7.9 Stabilization of the Highway Slope using Recycled Plastic Pins

The recycled plastic pin (RPP) is made from recycled plastics and waste materials (i.e., polymer, sawdust, fly ash, etc.). It is a lightweight material and is less susceptible to chemical and biological degradation than the alternative reinforcing element. RPPs are driven into the slope face and provide additional resistance along the slip surface which increases the factor of safety against shallow slope failure. The current paper summarizes a case study using RPPs to repair highway slopes, investigating

the use of a finite element method, and summarizes a design method. The highway slope was located over US 287 near the St. Paul overpass in Midlothian, Texas. The surficial movement had taken place over the slope, resulting in cracks over the shoulder near the bridge abutment. Three 15.2-m sections over the slope were reinforced using RPPs. After RPP installation, the slope was instrumented with inclinometers, rain gauges, moisture sensors, and water potential probes, and was monitored periodically. The performance monitoring results indicated that RPP provides resistance in the slope constructed using highly plastic clay. Further analysis of the slope using finite element analysis indicates that RPP can significantly improve the marginal slopes to a factor of safety more than 2.0. Finally, a simple design chart is presented to calculate the capacity of RPPs for slope repair design using an infinite slope approach.

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7.10 Use of Recycled Plastics in Asphalt Pavement Year 2

Over the last few years, there has been increasing interest in using recycled plastics in asphalt pavements. Recent studies have suggested that recycling plastics in asphalt mixtures is a great opportunity to improve the performance of pavements while eliminating the growing amount of waste plastics being landfilled or polluting the environment through litter. The goal of this study is to conduct a preliminary laboratorial investigation to explore the viability of using recycled plastics in asphalt in the state of Missouri. During the first phase of the project, the effects of high-density polyethylene (HDPE) on a typical Missouri asphalt binder PG 64-22 was investigated. 5% of HDPE (with or without pretreatment; flake or ground) by weight of neat binder was introduced into asphalt binder through wet process. Preliminary results indicated the size of recycled plastic flakes had significant effects on some properties of asphalt binders. The addition of HDPE greatly improved the rutting resistance of asphalt binders, and the binder modified with pretreated HDPE powders (with one physical treatment used in this study) has exhibited reasonable storage stability. The next phase of the project will aim to further investigate the methods to increase the compatibilization of waste plastics with asphalt and thus enhance mechanical properties of modified asphalt cement. The tests on binders with other plastics (e.g., polyethylene terephthalate (PET) and low-density polyethylene (LDPE)) as well as the mixture performance tests (i.e., semi-circular bending (SCB), Hamburg wheel tracking (HWT), and indirect tension (IDT) tests) will be conducted to evaluate the effects of different recycled plastics on the properties/performances of asphalt binders/mixtures. The results of this study are expected to identify whether recycled plastics can be successfully incorporated into asphalt with improved properties/performance. The issues resulted from the asphalt binders/mixtures modified by recycled plastics will also be identified.

https://tridurle.wsu.edu/use-of-recycled-plastics-in-asphalt-pavement-year-2/

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7.11 Evaluation of Recycled Plastic Modified Asphalt Mixtures: Phase I

With the changes in recycling streams over the past few years, the interest in diverting plastics from the waste stream for reuse in asphalt has been a growing topic for highway agencies. Several major knowledge gaps associated with the use of recycled plastics in asphalt were recently identified. Moreover, future research was recommended in many areas of the topic with particular focus on sourcing and methods of incorporating recycled plastics, material characterization of laboratory and field produced recycled plastic modified (RPM) asphalt mixtures, plant operations, health and safety, and mainly construction of field demonstration projects and associated short- and long-term performance. There is a mounting body of literature on the use of recycled plastic waste in asphalt but much of this documented work lacks a clear experimental plan and suffers from the use of dated test methods. Moreover, it is still unclear if producing and paving RPM mixtures would necessitate any

changes to typical paving practices in Virginia. The objective of this project is to document and assess RPM field trials constructed in Virginia. Moreover, this effort will document and evaluate the constructability, laboratory performance and initial field performance of RPM asphalt mixtures produced using plastic waste and typical raw materials in terms of aggregates and asphalt binders compared alongside with Virginia Department of Transportation (VDOT) typical control mixes. Along with an increased interest in the reuse of waste plastics, growing concern has been raised regarding the topic of microplastics in the environment. Therefore, this effort will attempt to detect and quantify the presence of microplastics in material generated from pavement wear that could potentially be mobilized via stormwater runoff.

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7.12 End-of-life tyres applications : technologies and environmental impacts

The worldwide consumption of tyres is growing, with an estimated global tyre production of approximately 2.2 billion tons in 2019. Tyres may contain a large variety of chemical compounds and therefore must be managed properly. On the other hand, end-of-life tyres contain several unique characteristics that make them suitable for multiple applications. This report focuses on analyzing end-of- life tyre management in Europe in general and Sweden in particular. The study also investigates the recycling technologies available in the market to manage end-of-life tyres. Furthermore, the expected environmental impacts for end-of-life tyres, in general, are investigated. The study is done based on a literature review, which is complemented with information obtained from interviews with relevant actors. In Sweden, end-of-life tyres are a substantial waste flow, accounting for approximately 85,000 tons per year. Sixty-five percent of tyres in Sweden are used as an energy source for energy production or in the cement industry, 34% are reused or recycled and 1% are exported. The report presents several opportunities for the use of end-of-life tyres (or materials) highlighting the material versatility. Examples include the use of tyre shreds as lightweight material or the use of granulated rubber in applications such as asphalt or concrete production. Many of the presented applications have a high potential contribution to a more circular economy. However, there is a need to better brand the applications as well link different stakeholders. Regarding the environmental analysis, the use of these end-of-life tyres may reduce the need of several virgin materials and reduces energy use. The literature analysis of potential leaching and human and environmental risks are inconclusive and there is still a lack of knowledge regarding leaching, bioavailability, toxicity and the related human and environmental risks in different applications. While some studies have shown that the use of end-of-life tyres materials is safe for the environment, others have shown a potential release risk of metals and PAHs. Therefore, the implementation of scientifically and risk-based regulations that define substances limits for tyre-derived products would potentially help the acceptance and use of these materials by users and contractors. Particularly for applications in which the tyre-derived products might be in contact with sensitive groups in the population, e.g. children. The standardization of tyre-derived materials with specific physical and chemical characteristics could be a step forward to increase the production of high-quality materials.

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7.13 Review of recycling waste plastics in asphalt paving materials

An ever-growing demand for depleted natural resources is one of the significant challenges facing the global asphalt pavement industry in building and maintaining global asphalt pavements. Because plastics are ubiquitous in the global economy, they are the latest in a series of high-profile materials to attract attention. Their low material recovery rates and the environmental impact of current disposal methods pose a threat to plastic recycling. Recycling plastic wastes in asphalt pavement is a possible approach to reducing environmental pressure and the demand for depleted natural resources. Many studies have proposed recycling plastic waste in asphalt pavement using dry- and wet-processed

technologies. This review aims to comprehensively evaluate the feasibility of various recycled plastics in asphalt pavement concerning the properties of compatibility, storage stability, microstructure, thermo-rheology, and mechanical performance and to identify challenges and recommendations for the future. This review discusses recent developments and the feasibility of using plastic wastes as modifiers or additives to asphalt binders or asphalt mixtures in dry and wet processes, focusing on different materials from waste streams, how to produce such modified materials, and the characteristics of plastic waste modified asphalt, thus contributing to the sustainable management of resources and production of useful paving materials.

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http://www.sciencedirect.com/science/article/pii/S2095756422000812

https://trid.trb.org/view/2037376

8 Stål, metal, slagg

8.1 Experimental investigation of asphalt mixture containing linz-donawitz (LD) steel slag

Standard asphalt mixtures for road infrastructures consist of asphalt binder and natural aggregate. However, over the past 20-30 years, the search for recycling alternatives has led departments of transportation, in US, and road authorities, in Europe, to consider a variety of potentially recyclable materials for pavement application. The list includes Reclaimed Asphalt Pavement, waste tire rubber, waste glass, and more recently, industrial by-products such as steel slag. A number of research efforts have successfully investigated the possibility of replacing the conventional aggregate skeleton with slag originating from steel production. However, it is not yet entirely clear how this by-product affects mixtures functional performance and properties such as stiffness, fatigue, resistance to low temperature cracking and permanent deformation. This paper presents a comprehensive and extensive experimental investigation on the fundamental performance properties of different types of asphalt mixtures prepared with 100% LD slag aggregate. A conventional asphalt mixture containing natural Gabbro aggregate was also prepared for comparison purposes. Low temperature cracking was addressed through Thermal Stress Restrained Specimen Tests. Cyclic confined and unconfined compression tests were used to evaluate the response of asphalt mixture to permanent deformation due repeated loading. The cyclic indirect tensile test was selected for investigating both stiffness properties and fatigue resistance. The results from stiffness and fatigue tests served as input for the current mechanistic pavement design system to predict the theoretical service life (durability) of asphalt pavements with LD slag compared to asphalt pavements having natural Gabbro aggregate. In addition, skid resistance properties were analyzed with the Wehner/Schulze Polishing machine and by calculating the Polished Stone Value. The experimental results and the analysis conducted in the present investigation indicate that asphalt mixtures prepared with LD slag are suitable for asphalt pavement construction and that in most cases they perform better than conventional asphalt mixtures prepared with Gabbro aggregate.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85003587550&doi=10.3850%2f978-981-11-0449-7-096-cd&partnerID=40&md5=d24ab634e1a279b718c19b6c4df5c735

8.2 Recent advances in the reuse of steel slags and future perspectives as binder and aggregate for alkali-activated materials

Steel slag (SS) is a secondary material from the production of steelmaking with little commercial value. It has several possible applications as raw material for different industrial process. However, small amounts are reused in some countries, where this material continues to be a burden to the steel industry. This paper presents the recent advances in the utilisation of SS in activities other than steelmaking. The main focus is the potential use of SS as binder and aggregates in cement-based materials, notably in alkali-activated materials (AAM). The latter are alternative construction materials to Portland cement (PC) and sometimes with lower environmental impact. The paper also

discusses technical and commercial challenges of employing SS as raw material, e.g. legislation barriers and need for thorough treatment processing. The findings indicate that SS is a well-established material in some applications, such as agriculture and road construction. The potential use of SS as cementitious material and aggregates for concrete is highly promoted in the literature. However, the major obstacles are the variable chemical composition of SS, expansion issues, and worse fresh properties when employed as aggregates. Those issues are detrimental to mechanical strength and durability. The use of SS as binder or aggregate for AAM is still incipient albeit promising. Studies on SS-based AAM present an improved interfacial transition zone, but still, low SS reactivity as a binder. The lack of durability studies and life-cycle assessment clearly shows the demand for further investigation. Overall, a great research opportunity is the employment of SS both as binder and aggregates in AAM.

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http://www.sciencedirect.com/science/article/pii/S0950061821003652

https://trid.trb.org/view/1778201

8.3 Alkali-Activated Controlled Low-Strength Material Utilizing High-Calcium Fly Ash and Steel Slag for Use as Pavement Materials

This study investigated the performance of alkali-activated, cement-based controlled low-strength materials (CLSMs). The CLSM was produced by mixing fly ash, steel slag, sodium hydroxide, and water with bottom ash (BA) aggregate. Properties of fresh and hardened composites were measured, and tests were conducted to determine their microstructure characteristics. Highlighted properties including slump flow, bleeding, unit weight, unconfined compressive strength, and resilience modulus were reported. The results indicated that the inclusion of 10%–30% slag resulted in a stronger CLSM with a higher Ca/Si ratio in the cementitious matrix of its microstructure. Higher slag content in the CLSM also shortened setting time and led to a lower bleeding rate. A mixture containing slag up to 20% of fly ash was recommended for pavement applications. Finally, the economic and environmental impacts were also preliminarily studied.

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https://trid.trb.org/view/1853651

9 Blandat och övrigt

9.1 Assessing the Economic and Environmental Effects of Gravel Recycling During Gravel Road Maintenance

Approximately 300,000 km of the Swedish road network consists of gravel roads. These roads contribute to accessibility and accessibility throughout Sweden, which is especially important in rural areas. An annual operation and maintenance grant is paid to these roads to be maintained and kept open to public transport, but the grant covers only part of the total maintenance costs. Some of the costliest maintenance activities are planing and gravelling. When gravelling, natural resources in the form of rock and gravel are used, which is an energy-intensive process that has a negative impact on the environment. A couple of methods exist for recycling of gravel from the roads, but the utilization is rather limited. In order to promote and motivate recycling of gravel, it is important to highlight the environmental benefits of using recycled gravel, but also to be able to assess the economic impact as additional costs may arise. The overall purpose of the paper is to gain deeper understanding of the environmental and economic effects of recycling of gravel during gravel road maintenance. To achieve this, a calculation model is developed to estimate the environmental impact and economic effects of gravel road maintenance. The purpose of the calculation model is to be able to compare alternative methods for gravelling. The calculation model is evaluated through a test scenario with three alternative methods for gravelling; two where gravel recycling is performed by the means of two

different methods and one in which new gravel is used. The test scenario shows that it is economically and environmentally beneficial, in a life cycle perspective, to use recycled gravel for road gravelling.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85127688319&doi=10.1007%2f978-3-030-96794-9_8&partnerID=40&md5=5f1de8b143940d10fbed6bb505ab9b1a

9.2 Development of a bridge circularity assessment framework to promote resource efficiency in infrastructure projects

Given the predominant use of virgin materials and the creation of vast amounts of waste in the construction sector, increasing its resource efficiency could result in a large improvement in overall use of resources. Bridges are a logical target for increasing resource efficiency, not only because of the large amount of materials involved but especially because a considerable number of bridges are demolished because of changing functional demands rather than technical failure. Furthermore, climate change increases future uncertainty and the likelihood of functionally motivated demolitions, which potentially exacerbates the creation of waste. Currently, it is not possible to measure and quantify the resource efficiency of bridge designs. In this study, a framework is presented that combines four indicators based on the principles of the Circular Economy. The four indicators are: (1) Design Input, (2) Resource Availability, (3) Adaptability, and (4) Reusability. Each indicator is further broken down into multiple sub-indicators. To test the usefulness of the proposed framework, it was applied to two real-world Dutch case studies. In addition, uncertainty and sensitivity analyses were conducted to determine the robustness of the indicator to changes in the design parameters and the weighting method used. Validation of the framework has shown that this bridge-specific circularity indicator is useful for determining the level of resource efficiency in terms of material use. This will allow clients to use resource efficiency, or circularity, as a selection criterion in the procurement process. This article met the requirements for a gold—gold JIE data openness badge described at http://jie.click/badges.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85102462343&doi=10.1111%2fjiec.13102&partnerID=40&md5=11170432b74e15deed64d18eb6ca10f7

9.3 Application of sustainable lignin stabilized expansive soils in highway subgrade

A by-product of the paper and wood industries, lignin is produced abundantly worldwide due to the increasing demand for wood and paper-based products. Improper disposal or storage of lignin is not only a misuse of natural resources but also poses a critical hazard to public health and the environment. Construction of highway subgrade has been identified as one of the feasible responses for consuming vast quantities of lignin to dispose of it in an ecologically sound manner, as it can be a low-cost and less energy-intensive chemical additive for soil stabilization. However, studies on the performance of lignin in stabilizing expansive soils in highway subgrade have been very constrained. Volume change resulting from seasonal moisture variations in expansive soil subgrades damages existing highways and complicates highway construction in expansive soil areas. To reduce expansive soil-induced geological disasters and utilize waste resources, the use of lignin could potentially be a sustainable solution for soil stabilization. In this research, a series of multi-scale laboratory tests were conducted to examine the Atterberg limits, the compaction and consolidation behavior, and the Fourier-transform infrared spectroscopy (FTIR) characteristics of lignin-stabilized expansive soils. The study reveals that the degree of lignin content impacts the physical, mechanical, and microstructural properties of the stabilized expansive soil. From the compression index (Cc) and swelling index (Cs) values, it was concluded that a satisfactory level of soil stabilization could be achieved by the application of an optimum percentage of lignin. The lignin-based cementing material bonds soil particles firmly together and fills the pores to produce a progressively steady soil structure.

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9.4 Unravelling the efficient use of waste lignin as a bitumen modifier for sustainable roads

The high cost and the environmental impact associated with using petroleum bitumen in pavement construction is a problem facing the asphalt industry. The study analyzes the effects of waste lignin on the properties (characterization, morphology, decomposition behavior, low and high-temperature behavior, fatigue resistance, deformation, adhesion bonding with aggregate in the presence of water and storage stability) of bitumen binders. The results show that increasing the lignin content, increased the cohesion and stiffening of the binder. Adding 10% lignin had a negligible influence on the workability and compaction characteristics of the asphalt mixture. The flow characteristics, of the lignin bitumen composite (LBC), at low and high temperature, decreased with increasing lignin content. Furthermore, the lignin fibers decreased the decomposition rate of the binder thus reducing the volatility of the binder (Co2 emissions). Dynamic Shear Rheometer test results revealed that adding lignin fibers to bitumen increased the rutting resistance of the binder while the linear amplitude sweep (LAS) results showed a decrease in the fatigue resistance. The multiple stress creep recovery (MSCR) results showed that LBC binder recovered better than the pure bitumen. In addition, LBC binder deformed less at different temperatures and stress levels. The LBC binder also had a better adhesion with aggregate as compared to bitumen. The study provides baseline information that complements past studies and can be useful to all stakeholders in the asphalt industry.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85072574462&doi=10.1016%2fj.conbuildmat.2019.116957&partnerID=40&md5=314eb52ff26877d61f28591942affbad

9.5 A review of recycled aggregates (RAP and RCA) as unbound base course material for sustainable highway construction

This paper presents a review of unbound recycled materials, specifically recycled asphalt pavement (RAP) and recycled concrete aggregate (RCA), as road base course for sustainable highway construction. A total of fifteen recycled materials were collected for characterization and testing from across the USA. Compaction characteristics and resilient moduli of these samples were determined and predictive equations were derived. Test sections were constructed using recycled materials in the granular base layers at the MnROAD test facility. Large-Scale Model Experiments (LSME) replicating field-scale conditions were also conducted and scalability of various scale modulus measurements was investigated. When compared to conventional base course, RAP and RCA experienced higher modulus. Discussion includes mechanical and durability characteristics, and leaching behavior. Sustainability evaluation of material alternatives in a project is described.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85059168193&doi=10.1007%2f978-981-10-6713-6_1&partnerID=40&md5=77801ce140ccb7de1d1c12abad099905

9.6 Beneficial reuse of Brest-Harbor (France)-dredged sediment as alternative material in road building: laboratory investigations

The scarcity of natural aggregates promotes waste reuse as secondary raw material in the field of civil engineering. This article focuses on the beneficial reuse of marine-dredged sediments in road building. Thus, mixtures of raw sediments and dredged sand collected from Brest Harbur (Bretagne, France) were treated with road hydraulic binders. Formulation were prepared and characterized as recommended by the French Technical Guidelines for soil treatment with lime and/or hydraulic binders. Mechanical resistance results are quite similar for both the hydraulic binders, suggesting a similar reactivity with the studied sediment sample. However, some discrepancies can be noted on sustainability parameters. Indeed, water resistance after immersion at 40°C is significantly better for the mixtures treated with cement containing more glass-forming oxides ($SiO_2 + Al_2O_3$) and fluxing (Fe_2O_3+CaO + MgO + K_2O + Na_2O). Moreover, the both hydraulic binders can lead to swelling in the road materials as observed in scanning electron microscopy analyses. Indeed, microscopic observations indicated volumetric swelling of treated samples, which is greatly influenced on the one side by ettringite quantity and on the other hand by the presence of water in pores material.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85017274800&doi=10.1080%2f09593330.2017.1308440&partnerID=40&md5=a3c0596a1de01bc1014fbe1c8b39b957

9.7 Securing a port's future through Circular Economy: Experiences from the Port of Gävle in contributing to sustainability

Ports are an important player in the world, due to their role in global production and distributions systems. They are major intermodal transport hubs, linking the sea to the land. For all ports, a key requirement for commercial and economic viability is to retain ships using them and to remain accessible to those ships. Ports need to find approaches to help them remain open. They must ensure their continued economic viability. At the same time, they face increasing pressure to become more environmentally and socially conscious. This paper examines the approach taken by the Port of Gävle, Sweden, which used contaminated dredged materials to create new land using principles of Circular Economy. The paper demonstrates that using Circular Economy principles can be a viable way of securing a port's future and contributing to its sustainability, and that of the city/region where it operates.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85044680804&doi=10.1016%2fj.marpolbul.2018.01.065&partnerID=40&md5=f0210cb7ecbca454df0acbb824bdc41e

9.8 Dredged Marine Sediment as Raw Material in Civil Engineering Applications

Huge amounts of dredged marine sediments are generated periodically in order to maintain waterways and ensure ships navigation. After dredging, marine sediment are either discharged at sea or disposed in lands. Nowadays, dredged sediment reuse in civil engineering applications become more and more a beneficial tool for waste material management. Indeed, various reuse ways have been studied such as road construction, clays bricks, cementitious materials and paving blocks. Sediment characteristics are the primary decision maker in choosing the adequate valorization way. Thus, laboratory identification is an essential step in sediment management. Physical, mechanical, chemical, mineralogical and environmental properties of dredged marine sediments define the possible civil engineering applications according to standards. This works is divided into two main sections. In the first part, a literature review of sediment reuse is presented. The choice of alternative reuse is based on geotechnical, mechanical, chemical, mineralogical and environmental characterization of marine sediment. Possible sediment reuse in civil engineering applications are classified according to material proprieties. The second part, deals with two different applications of marine sediment dredged from two Tunisian harbors. Sediment extracted from the first study area, Zarzis commercial harbor, was reused as a new material for road construction. The mechanical tests of various formulations conducted on different mixtures are compaction and compression. The experimental results showed the feasibility of Zarzis sediment with 3% lime addition in road applications in base-course material. Sediment from Gabes harbor is the second investigated sample. Based on its characteristics, this material could be reused in concrete formulation. Results revealed that the substitution of 20% of sand volume by Gabes channel sediments provided a concrete with higher compression strength than reference one. © 2018, Springer International Publishing AG.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85102630124&doi=10.1007%2f978-3-319-61612-4_33&partnerID=40&md5=8bc6083ff0c80a08b7a8c1c4ae091136

9.9 Sustainable Application of Quarry Byproducts Mixed with Large Size Unconventional Aggregates for Improved Performance

With recent focus on sustainable construction practices and the ever-increasing transportation costs and scarcity of natural resources, integration of large-size unconventional and marginally acceptable aggregates, such as quarry by-products (QB), and making their routine use in construction specifications is becoming imperative. In this study, the stability of large-size aggregates is increased

by adding QB as sand- and smaller-sized particles to fill up the voids. Adding QBs is expected to increase density and provide stability for better aggregate interlock, and therefore, to increase the subgrade strength and eventually improve the road's rutting performance. In order to determine the appropriate weight mix ratio of the large-size aggregates and the fine QB materials, a steel box with dimensions 610 mm by 610 mm by 533 mm was built to assess the packing of the two materials. One of the sides of the box was designed to have a transparent Plexiglas that enabled observation of the QB percolation into the voids of the large-sized aggregates, which were added in multiple lifts. The QB materials were then evenly spread on the surface of each lift and compacted with a laboratory-sized roller compactor. Different mix ratios, support conditions, and moisture contents of the QBs were investigated. The study concluded that 25% QB by the dry weight of the large aggregates is an appropriate amount to be used for both one- and two-lift construction practices of this composite weak subgrade replacement aggregate material, i.e., aggregate subgrade, in the field. The laboratory results will be implemented in the field by constructing test sections for unpaved construction platform and asphalt-paved low volume road applications and monitoring them for rutting performance using an accelerated pavement testing device.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85102117033&doi=10.1007%2f978-3-319-61633-9_17&partnerID=40&md5=5b2b89036ea824f53cbcc747db61c382

9.10 Leaching behaviour of copper slag, construction and demolition waste and crushed rock used in a full-scale road construction

The leaching behaviour of a road construction with fayalitic copper slag, recycled concrete and crushed rock as sub-base materials was monitored over ten years. All studied materials used in the road construction, including crushed rock, contained concentrations of several elements exceeding the guideline values recommended by the Swedish EPA for total element concentrations for waste materials used in constructions. Despite that, leaching from the road construction under field conditions in general was relatively low. The leachates from the recycled materials contained higher concentrations of several constituents than the leachates from the reference section with crushed rock. The leaching of the elements of interest (Cr, Mo, Ni, Zn) reached peak concentrations during the second and fourth (Cu) years and decreased over the observation period to levels below the Swedish recommended values. Carbonation of the concrete aggregates caused a substantial but short-term increase in the leaching of oxyanions such as chromate. The environmental risks related to element leaching are highest at the beginning of the road life. Ageing of materials or pre-treatment through leaching is needed prior to their use in construction to avoid peak concentrations. Also, the design of road constructions should be adjusted so that recycled materials are covered with low-permeability covers, which would minimize the exposure to atmospheric precipitation and weathering.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85030104861&doi=10.1016%2fj.jenvman.2017.09.032&partnerID=40&md5=543af77e8c9b769a45b0435589824b8b

9.11 Sustainable field applications of quarry byproducts mixed with large size unconventional aggregates

Quarry Byproducts (QBs), usually less than 6 mm in size, are the residual deposits from the production of required grades of aggregate and often stockpiled in excess quantities at the quarries. Recent research at the Illinois Center for Transportation has focused on investigating the performance of large-size aggregates mixed with QB for constructing subgrade replacement and subbase over weak soils. Such a sustainable application linked to commonly used rockfill practice for building construction platforms and low volume road applications over soft subgrade would improve the stability when large aggregates are mixed with QB materials. The appropriate weight mix ratios of the large-size aggregates and the fine QB materials were determined via a laboratory packing study. A combination of 30% dry QB by the weight of the large rock and 25% QB with a moisture content of 2.5% were found to be the optimum quantities of QB to be mixed with the large-size rock on top of a

soft subgrade. In the field, two test sections were built to study the construction platform application by shaking and compacting the QB on top of large, 100 to 150 mm, size aggregate materials in one and two lifts using a vibratory roller compactor with the goal to construct a 530-mm layer, topped with 76-mm of regular-sized dense graded capping aggregate material. Other two test sections that were also built as the exact replicates of the construction platform sections were paved with an additional 100-mm thick hot mix asphalt surface to study the low volume road application. Performance monitoring of the unpaved construction platform sections indicated that both the one-lift and two-lift sections showed a good performance under a heavy wheel load by accumulating less than 76 mm of rutting after 20,000 load repetitions.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85058570941&partnerID=40&md5=610e5ec4dced62a107ea53eb0eaa5b6d

9.12 Pavement design considerations for subgrades stabilized with recycled materials

This paper is aimed at identifying and characterizing pavement design considerations associated with using recycled materials for pavement subgrade stabilization. Traditionally, remove-re-place option or stabilization with cement, lime, asphalt or other manufactured chemicals are used for subgrade improvements, when poor, unstable subgrade soils were encountered. Due to rising cost of these traditional stabilizers and the fill materials, highway and airport agencies are looking for recycled materials for subgrade stabilization. These recycled materials include Cement Kiln Dust (CKD), Lime Kiln Dust (LKD), Fly Ash (FA), Concrete Fines (CF) and others. An extensive laboratory study was performed to characterize the short-term, and long-term performance of subgrade soil samples stabilized with recycled materials. Using the laboratory test results, pavement design inputs were developed from a limited analytical investigation. The developed pavement design parameters include the stabilized layer moduli values for mechanistic-empirical pavement designs and structural layer coefficients for 1993 AASHTO pavement designs.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85058566818&partnerID=40&md5=741ec1371042bdf9b0b7293287f146b7

9.13 Performance properties of asphalt mixture containing linz-donawitz (Ld) steel slag

Standard asphalt mixtures for road infrastructures consist of natural aggregate and bitumen. A number of research efforts have successfully investigated the possibility of replacing the conventional aggregate skeleton with industrial by-products such as slag originating from steel production process. However, little is known on the effect of steel slag on the mixtures performance properties such as resistance to low temperature cracking and to permanent deformation, stiffness and fatigue. In the paper the results of a comprehensive investigation on the fundamental performance properties of different types of asphalt mixtures prepared with 100% LD slag aggregate and a conventional asphalt mixture containing natural Gabbro aggregate are presented. Sophisticated testing methods were used to evaluate the key performance parameters for the set of asphalt mixtures investigated. In this study, low temperature cracking was addressed through Thermal Stress Restrained Specimen Tests. Penetration Tests and Cyclic Compression Tests were used to evaluate the response of asphalt binder and asphalt mixture to permanent deformation due repeated loading, respectively. The Cyclic Indirect Tensile Test was selected for investigating both stiffness properties and fatigue resistance. For this purpose the complex stiffness modulus was measured to quantify material stiffness under different temperature and loading conditions providing information on the visco-elasto-plastic material behavior. Fatigue tests were used to determine the progressive and localized material damage caused by cyclic loading. The experimental results indicate that asphalt mixtures prepared with LD slag are suitable for asphalt pavement construction and that in most cases they perform better than conventional asphalt mixtures prepared with Gabbro aggregate.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85058519202&doi=10.1201%2f9781315100333-47&partnerID=40&md5=7e5c90d9586d29bc82526105004d6a20

9.14 Use of recycled drill pipes for soldier piles and anchored walls for roadway embankment reconstruction

Recycled materials are often selected for transportation construction for their environmental or sustainability benefits. But they can also be used to create projects that are low cost, simple, and efficient to build. This paper describes development of standard details for creating retaining walls from recycled high-strength drilling pipe and used metal beam guard rail. Construction of these walls is inexpensive and efficient because they use only readily available material, require no specialized equipment or labor, and can often be done without requiring road closures. During el-Niño fueled rainy seasons Santa Barbara County is often inundated with drenching rainstorms that cause landslides, debris flows, and embankment failures. These failures close miles of roads and isolate people from lifeline services. The County needed a way to quickly and safely stabilize and reopen roads with a supply of contractors, equipment, and materials that are limited during large storm events. Out of these emergency response efforts Santa Barbara developed standard details for several slope stability repair options using low-cost, readily available equipment, material and labor. An emphasis was placed on designs that would get roads open quickly. Using recycled high-strength drill pipe for piles and used metal beam guard rail elements for lagging, the county created standard design details for soldier pile walls up to 4 feet tall, and anchored walls up to 8 feet tall. These walls can be built in days, not weeks or months. And they only require these materials and a few other readily-available components. As a result, roads can be opened and back in service within days of an embankment failure, restoring access for emergency services and residents.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85018793534&doi=10.1061%2f9780784480458.046&partnerID=40&md5=fc05ffe709ee65b6b52ea58b0364044b

9.15 Harvesting the unexplored potential of European waste materials for road construction

This paper demonstrates how a considerable amount of waste produced in the urban and peri-urban environment can be recycled in asphalt roads. The example presented is from Europe, however, the barriers and conclusions are universal. It was shown that various waste materials such as glass, asphalt, concrete, wood, plastics etc. have a potential for re-use in asphalt roads. The available quantities of the European target waste materials that would otherwise be incinerated or disposed in landfills were considered. It was shown that there is high potential in Europe for recycling in road construction, in particular, under the hypothetical scenario where 33% of new roads would be made of the target waste materials (excluding RAP which is already recycled), it is estimated that 16% of the available waste quantities could be recycled in roads. Four hypothetical roads were analysed showing a considerable savings in costs, CO2 and energy in comparison to conventional asphalt mixtures using all virgin components.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-84987923376&doi=10.1016%2fj.resconrec.2016.09.008&partnerID=40&md5=a35655b8c237e9738f510bcd799078f6

9.16 Use of recycled materials in road construction

With the evolution of the road industry and growing traffic on roads, construction materials have also been evolved and more unconventional ingredients have been incorporated. The rationales was the scarcity of conventional natural materials and the jeopardized environment which have underpinned the tendency towards evaluation other materials resources to be incorporated in the road industry. The inclusion of such materials entails several secondary and tertiary materials. Several waste by-products and materials have been investigated, assessed, evaluated for utilizations and practiced in the field.

Depending on the attributes of the characteristics of the recycled material, the inclusion varies. Some recycled material have been proven to possess preferable properties over the other and have performed satisfactorily in the field. However, there are numerous concerns regarding such incorporation based on both laboratory experimental, and field observations which have turned out to be of the essence for further in-depth studies. Reclaimed asphalt pavement, recycled concrete aggregates, plastic wastes, scrap tires, mine wastes, recycled crushed glass, foundry sand, coal combustion products as fly ash, bottom ash, and pond ash, steel slag, oil sand, oil shale sand, lateritic soil, are amidst the long list. It is believed that magnificent preservation of natural and precious resources would be attained from the inclusion of secondary and tertiary materials in road construction. Nonetheless, without rigorous cooperation between the academia and the industry and educating people who are in routinely interact with paving activities, several performance-related issues would not be resolved and would remain in existence. This paper present a literature review report on the most viable recycled materials currently in practice by the industry and it aims towards developing a noble idea on better inclusion of a recycled material in the road industry.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85091105299&partnerID=40&md5=157f9f1c72cddf37e11b6b56bf438961

9.17 Sustainability case study review of using recycled aggregate in road structure

Many transportation agencies are working towards more sustainable infrastructure management practices. One way in which agencies are being sustainable is by using recycled aggregates in road structures. It is important to evaluate the sustainability of these alternative road construction methods compared to the sustainability of traditional road construction methods. This paper reviewed the sustainability of rehabilitated road structures constructed using crushed reclaimed asphalt and cement concrete rubble. Four key aspects of sustainability were considered-economic, social, environmental and technical. A City of Saskatoon "Green Street" Infrastructure Program case study is presented in this paper. From an economic perspective, significant costs savings are observed compared to the use of traditional virgin road aggregate materials. From a social perspective, residents who use the rehabilitated road will see an equal or improved level of service compared to a traditional structure. This is observed through the use of non-destructive heavy weight deflection (HWD) measurements where the deflection measurements on the recycled structure were less or equal to a traditional structure. The cost savings with the use of recycled materials may also be reinvested into rehabilitating more roadways improving the overall performance of the roadway network for residents. Environmentally, because recycled materials are typically locally available and aggregate shortages are forcing justiditions to haul virging aggregates from futher away, fewer emissions are generated due to shorter distances for trucking and less energy is required to be consumed. Less virgin materials are required to be extracted from the earth and less waste material is also generated by recycling construction rubble. Technically, the mechanistic properties of the recycled materials were found to be equal or superior when compared to conventional road building materials. Laboratory and field measurements indicate that under higher applied stress state field conditions, the recycled materials exhibit performance measures that exceed that of conventional granular materials. This study illustrates that recycled materials can be used effectively in sustainable road construction when applied within a framework of applied engineering computational mechanics for design and analysis.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85090534987&partnerID=40&md5=697adf4d65ad9e40873e3492ebb89e6b

9.18 Eco-friendly Materials for a New Concept of Asphalt Pavement

It is estimated that more than 90% of the 5.2 million kilometers of European paved roads and highways are surfaced with asphalt. Also, about 44% of goods are transported by road in the EU; maintaining their condition whilst in transit is crucial for the economy. The construction of a new road has a number of implications for the environment, consuming large amount of materials and energy. Also, the price of crude oil, which is the major source of bituminous binder, has significantly increased

in recent years (the most noticeably in 2001-2008). This has led to an increase in the total price of asphalt mixtures. In order to promote sustainable practices and to combat price increase, measures with sound sustainability credentials need to be widely implemented. Developing novel materials and technologies to integrate greener material, waste and recycled materials into the production cycle of asphalt mixtures is a solution that improves both sustainability and cost-efficiency of the asphalt pavement industry. The main concept presented in this paper is the application of an eco-innovative asphalt pavement designed through partial substitution of greener materials into asphalt mixtures: reclaimed asphalt pavement (RAP), construction and demolition waste (C&DW), lignin (by-product of 2nd generation bioethanol processing) and bio-binder from vegetable oil. This paper discusses a new concept of an asphalt pavement structure with ecologically oriented attributes, achieved whilst maintaining a level of long term performance comparable or greater than that of conventional pavement structures. The two main components of asphalt mixture - bitumen and aggregates - are focused upon. In relation to bitumen, two methods to 'green' the fresh binder fraction are explored: The first investigates bio-fluxing bitumen, which enables part of the petro-chemical binder to be replaced with bio-based products; the second uses a specific industrial waste, also bio-derived, to replace the crude-oil derived polymer in modified bitumen. In relation to aggregates, two different approaches are also explored: The use of high rates of reclaimed asphalt pavement (RAP) in new hot asphalt mixtures, thanks to the addition of bio-fluxing agents which will allow working at lower temperatures, and the use of construction and demolition waste (C&DW). Optimal integration of C&DW as raw material will be established using a selective process for the separation of C&DW to increase the overall quality of the recycled aggregates. Considering the full pavement structure, the main innovations can be summarized as follows: (A) in surface course is the introduction of green bitumen modifier, derived from recovered waste bioethanol production as an alternative to the traditional additives used for polymer modification; (B) in binder and base course, bio-fluxing agents allow for the integration of higher percentage of reclaimed asphalt; and (C) the lower layers (sub-base and subgrade) are mainly composed of materials derived from construction and demolition waste. This paper describes the systematic approach for selecting the right combination of these main pavement components in the design of asphalt mixtures, from laboratory tests to real applications. This approach has been developed by a consortium of partners in the FP7 funded Asphalt Pavements for a Sustainable Environment (APSE) project.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-84991736322&doi=10.1016%2fj.trpro.2016.05.426&partnerID=40&md5=8423e56567e90dcff9e784ba32fcc757

9.19 Sustainable roadway construction using recycled aggregates with geosynthetics

- Concrete, asphalt pavements, and ballast are removed during the re-construction of existing roads and have been increasingly recycled as aggregates for the construction of roadways. Due to existence of asphalt, cement, and fines, mechanical properties of recycled aggregates may not be sufficient for load support. They may also have long-term durability problems. Geosynthetics have been used to improve mechanical properties and long-term durability of recycled aggregates. This paper reviews recent research work on the use of geosynthetics to stabilize recycled aggregates in roadway construction and summarizes the main findings on permanent deformation, creep deformation, degradation, stress distribution, and/or crack propagation.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-84926406922&doi=10.1016%2fj.scs.2013.11.011&partnerID=40&md5=031a0af00a30ce7d4ada3362ca8ebc59

9.20 The greening of civil infrastructure

Recycled industrial materials are increasingly finding their way into the construction of highways, roads and bridges. This takes manufacturing byproducts out of the waste stream and reduces the manufacture of new products and extraction of resources. Industrial byproducts such as coal

combustion materials, construction and demolition debris, spent foundry sands, steel slag and used rubber serve as sustainable alternatives to virgin materials and construction products. Using fly ash as a partial substitute for Portland cement in concrete enhances the durability of the concrete surface. Even recycled rubber tires have utility: as an asphalt binder modifier, they are sometimes used to replace polymers and may help make asphalt pavements quieter and less prone to cracking.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-84927126804&partnerID=40&md5=590dee96d63b09b6f62ee1b331f4f319

9.21 Utilization of wood ash as a road construction material-sustainable use of wood ashes

In Finland about 500 million kg of wood and peat ashes are produced annually. Although the utilization of wood ash (i.e., utilized as a fertilizer or in road construction and landscaping) has increased, a significant part of wood ash is still landfilled. That could be seen as a waste of potentially valuable resources as well as clearly against the main target of the recycling society. Based on the chemical and physical properties of wood ash, it could be used as a road construction material for low level roads. Wood ash could be used as building material as well as a binder for the stabilisation of soft soils. However, there is no environmental or technical data available from forest roads that could be potential places where apply wood ash as a road construction material in high volume. For example in Finland about 4000 km of forest roads should be prepared annually. In forest roads wood ash could be apply in upper road layers without pavement. However, there is no data available whether the trace elements of these kinds of road structures will be leached and transported deeper down in the profile of forest road layers. The paper will focus on the utilization of wood ash (fly ash) as a road construction material and its environmental effects on the chemical properties of groundwater and soil; pH, alkalinity, conductivity and the most harmful elements; As, Cd, Hg and Pb, potentially found in wood ash. The large-scale field experiment was established in the autumn of 2011. The study site is located in central Finland (Karstula). The field experiment consists of 14 forest road sections, each 200-300 m that handled with different mixtures of wood ash and gravel including control (gravel without ash). The environmental impact of the road structures was monitored from groundwater samples taken over a period of two years. Also soil samples from the lower road layers were taken in order to monitor the possible development of element concentrations in the lower layers of road structures. The preliminary results after two year tracking indicate that the road structures (mixture of wood ash and gravel) will not cause changes in the environmental parameters measured in the study.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-84910642522&partnerID=40&md5=b2a4c0d26a2968719a88b9500694a2c8

9.22 Recycling of road materials into new unbound road layers - main practice in selected European countries

Most European countries are active in the field of recycling road materials, but knowledge and practice differ between countries. The European project DIsmantling and RECycling Techniques for road MATerials - Sharing knowledge and practices aims at sharing knowledge and practice in this field among the 15 participating countries, with the view of drafting European best-practice guidelines. This paper reports on the first step towards this goal, which consists of summarising documented practices within these countries concerning demolition and recycling of road materials back into new unbound road layers. Common documented practice and major differences between European countries are highlighted and put in perspective, thanks to a broader international document review.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-84879693003&doi=10.1080%2f14680629.2013.794369&partnerID=40&md5=8c1ca2fc22bb2c729711d24d21cae9d3

9.23 Recycled materials in roads and pavements: a technical review

The aim of the Guide and Technical Review is to promote national uniformity and good practice in the specification and application of recycled material reuse in roads and pavements. The requirements in these documents are applicable to engineering projects for local roads and pavements carried out by local councils. This Technical Review document comprises of six chapters revolving around the use of recycled materials in roads and pavements: Chapter 1: An overview of the circular economy; Chapter 2: Current relevant waste streams; Chapter 3: A review of the technology; Chapter 4: Occupational Health, Safety and Environment Risk Assessment; Chapter 5: Evaluation and monitoring; Chapter 6: Case Studies.

https://lgnsw.org.au/common/Uploaded%20files/PDF/Technical_Review_Recycled_Materials_in_Roads-Pavements.pdf

9.24 Use Of Recycled Materials In Pavements: A PIARC Briefing Note

Back in 2003, the World Road Association (PIARC) published a report from Technical Committee C7/8 on “Pavement Recycling”. This report contains guidelines for in-place recycling with cement, emulsion or foamed bitumen and hot mix recycling in a plant. The current briefing note is the final part of a set of three reports on the “Use of Recycled Materials in Pavements”. This briefing note contains the conclusions and recommendations on recycling pavement materials deriving from the previous “Literature Review” and “Collection of Case Studies” reports. The scope of the note covers: Recycling in-place using hydraulic and/or bituminous binders, it also addresses the preliminary investigations of the existing pavement prior to recycling; Recycling or re-using in-plant where the recycled materials are prepared and mixed in plant, adding hydraulic or bituminous binders, to produce a mix for asphalt or concrete pavements, or for road base layers.

https://www.piarc.org/en/order-library/37604-en-Use%20Of%20Recycled%20Materials%20In%20Pavements?directory=%7B%7D

https://trid.trb.org/view/1943794

9.25 CEDR Resource Efficiency and Circular Economy.

Lindgren,Åsa, Trafikverket

SN - Trafikverket 2020/73341

CEDR forskningsprogram med syfte att påskynda omställningen till resurshushållning och cirkulär ekonomi. Utlysning 2020; CEDR research program. The aim of this research program is to accelerate the transition of the road infrastructure sector in Europé, from linear economy into resource efficient circular economy.

9.26 CEDR TRANSNATIONAL ROAD RESEARCH PROGRAMME Utlysning 2017 - Nya material

Karlsson,Robert, Trafikverket

SN - Trafikverket 2017/106916

Detta projekt är en del i den av CEDR internationellt finansierade utlysningen "CEDR Call 2017: New Materials". Programmet utvecklades genom ENR (ERANET Road) och sen vidare av WG Innovation för att möta intressen från CEDR (Conference of European Directors of Roads). Det övergripande målet med det transnationella forskningsprogrammet "New Materials & Techniques" är att utveckla koncept och strategier och visa att de är användbara för att öka vägbeläggningarnas hållbarhet på lång sikt, samtidigt som man säkerställer ett minskat beroende av råmaterial och lågt fossilt energibehov. Lösningarna måste vara genomförbara, beprövade och kostnadseffektiva. Utlysningen har tre underteman: A: Tillförlitlig livscykelkostnads och nyttoanalys av "grön asfalt". B: Förenkla användningen av returasfalt C: Användbarhet av supermaterial; This Transnational Road Research

Programme has the title “CEDR Call 2017: New Materials”. The Programme was developed initially within the framework of ENR (ERANET Road) and was then taken forward by WG Innovation to fulfil the common interests of the national road administration members of CEDR. The overall aim of the Transnational Research Programme “New Materials & Techniques” is to develop concepts and strategies and to demonstrate their applicability to increase the long-term durability of pavements while at the same time ensuring a reduced dependency of raw materials and a low fossil energy demand. The solutions must be feasible, proven and cost-effective. The Call has three sub-themes: A: Reliable life cycle and social cost-benefit analysis of “green asphalt”; B: Simplifying the use of RAP; C: Usability of Super Materials

10 Flygplatser

10.1 Use of Recycled Asphalt Pavement (RAP) in Airport Pavements

Federal Aviation Administration (FAA) currently does not allow use of recycled asphalt pavement (RAP) on Airport Improvement Program (AIP) funded airport runway and taxiway pavement projects, and is allowed for use only in pavement shoulders. FAA’s National Airport Pavement and Materials Research Center (NAPMRC) was established to evaluate performance of new and sustainable asphalt material technologies (such as WMA, RAP, etc.) under heavy aircraft loading at high pavement temperatures. As part of Test Cycle 2 (TC2), six test lanes were constructed – four outdoors and two indoors, each encompassing three different test sections. In two indoor lanes, RAP was added to the warm mix asphalt (WMA). Lane-1 is the control section with FAA standard P401 specification hot mix asphalt (HMA). Heavy weight deflectometer (HWD) tests were performed on the constructed test lanes to characterize the pavements. Extensive laboratory tests are planned on RAP/WMA and HMA (field cores and loose mixes). The test lanes will be subjected to accelerated pavement tests (APT) using custom designed airport heavy vehicle simulator (HVS-A) to study rutting performance (at high pavement temperatures) and fatigue behavior. This paper presents construction of test lanes, asphalt mix designs (with and without RAP), results from HWD tests on test lanes with RAP/WMA, and results from laboratory tests on pavement materials.

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10.2 Towards airfield pavement design using cold recycled bound materials

Using Cold Recycled Bound Material (CRBM) is a sustainable technique that saves energy and raw material consumption. This technique is widely used in UK roads but its application in airfields is limited as there is no specific pavement design guidance for using CRBM. As part of the author’s research in the SUP&R ITN project this paper proposes appropriate design guidance for using CRBM in airfield pavements. With this aim an analytical approach using a multilayer elastic model (Kenlayer) was used to analyse different airfield pavements with conventional asphalt materials for specific loading and subgrade conditions. First, pavement designs obtained from Kenlayer were compared to those from an existing design guide, namely DMG 27 from Defence Estates, UK, to prove the suitability of the approach and inputs for airfield design purposes. After this, the software was used to analyse pavement structures where CRBM was substituted for asphalt concrete in the base layer. The material properties were assigned based laboratory testing and established design parameters. The results show that different asphalt concrete and CRBM layer thicknesses were needed for the same design conditions, due to the different material properties. This allowed an appropriate factor to be derived to increase the thickness given by DMG27 (or any conventional airfield pavement design method) to account for a CRBM base.

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