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亚洲沥青生产商与消费者之间的桥梁

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EDITOR'S MESSGAE

With a decade of activity in the bitumen and petroleum derivatives industry in the field of printing and publishing specialized news and selected scientific articles from conferences, symposiums, research centers and universities, and introducing brands and companies producing petroleum and bitumen, the World of Petroleum and Bitumen Journal has been able to gain the trust of more than 6000 permanent audience in such a way that they would like to receive the print version of the journal every month.

Ali farjam

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比尔·盖茨的碳吸收沥青开始在现实中应用

大约一年前，比尔·盖茨造访了位于西雅图的现代氢能公司总部——这是一家他投资的环保科技企业。在一次演示中，他亲手填补了一个测试坑洞，使用了一种新型沥青。尽管在操作建筑工具时显得有些笨拙，这位亿万富翁慈善家仍展示了一项极具前景的创新：一种注入了捕获碳的道路表面材料。

这种材料被称为“Modern Carbon（现代碳）”，其中包含从天然气中提取的固态碳。这些碳被提取出来并封存在沥青中，形成一种能够实现碳封存的混合物，其功能与传统路面相同。据该公司高级产品开发经理迈克尔·巴巴（Michael Baba）介绍，这块测试路面在经历了一年的日常交通后仍保持完好。“它与道路完美融合——这正是一块高性能沥青应有的表现，”他指出。

现代氢能成立于2015年，并得到了盖茨的支持。公司开发出了一种独特的甲烷热解反应器工艺。该装置可将甲烷（来源包括化石燃料或可再生资源如粪肥）分解，生产出仅排放水蒸气的清洁氢气。而其副产品——提取出的固态碳——可以直接用于沥青中，替代石油基的沥青胶结料。这一转变不仅降低了温室气体排放，还实现了永久性的碳封存，同时可降低多达20%的材料成本。

考虑到沥青覆盖了全球约90%的道路，而沥青胶结料是该行业碳足迹的主要来源，这项创新的潜力巨大。现代氢能表示，使用现代碳材料可减少20%的材料排放，并将道路生命周期的整体排放降低11%。

这种新型沥青在抗车辙和抗裂性能上的优异表现也获得了美国国家州高速公路与运输官员协会的认可，并符合ASTM国际标准。

自2024年初盖茨亲自演示以来，该材料已从原型走向实际应用。2024年11月，德克萨斯州贝克萨尔县在与克拉克建筑公司的合作下，在圣安东尼奥的道路维护中铺设了100吨该产品。

贝克萨尔县公共工程部主管亚伦·马丁内斯（Aaron Martinez）表示乐观：“我们一直在探索更好的材料。碳封存沥青无疑是我们未来的一部分。”

此后，现代碳已在美国多个州和加拿大多个省份（包括阿尔伯塔省）得到了应用。在纽约长岛，现代氢能与国家电网公司合作，在更换燃气管线时同步使用该材料，减少了排放并提升了基础设施建设效率。

此外，一些社区项目也开始使用该材料。在加利福尼亚州长滩，信仰之家基督教中心用大约100吨该材料修复了其停车场。在华盛顿州斯诺霍米什，一段长达一英里的住宅道路也使用了现代碳进行了翻修，展示

了其在社区规模项目中的有效性。

尽管现代碳受到广泛关注，但更广泛的行业趋势也在持续推动降低沥青对环境的影响。据国家沥青路面协会的数据，从2009年到2022年，回收沥青在新建道路中的使用比例从15.6%上升到22.2%。

这些发展体现了基础设施行业对可持续性和创新材料日益增长的承诺。

丹佛拒绝本地沥青合同，选择来自加拿大和威斯康星州的道德采购渠道

据WPB报道，丹佛市决定不再从科罗拉多州本地采购沥青，而是选择来自加拿大和威斯康星州的供应商。此前，市议会一致否决了一项与森科能源公司（Suncor Energy）签署2500万美元合同的提案，该决定源于对环境和道德问题的担忧。

这项拟议的为期五年的协议本计划与位于科罗拉多州康默斯城的一家主要炼油厂——森科能源签订。然而，由于该公司长期以来在环保方面的问题，该提案被否决。尽管森科是该地区主要的铺路级沥青供应商，但其多次因污染周边社区而备受批评。

市议员阿曼达·索耶（Amanda Sawyer）对该提案表示反对，指出市政府曾承诺不与那些被认为对本地社区有害的企业签约。她特别提到森科对北丹佛地区造成的负面影响，并质疑该合同是否符合城市的价值观。议员尚特尔·刘易斯（Shontel Lewis）也表达了类似看法，称该炼油厂是该地区历史性与持续性不公正的象征。

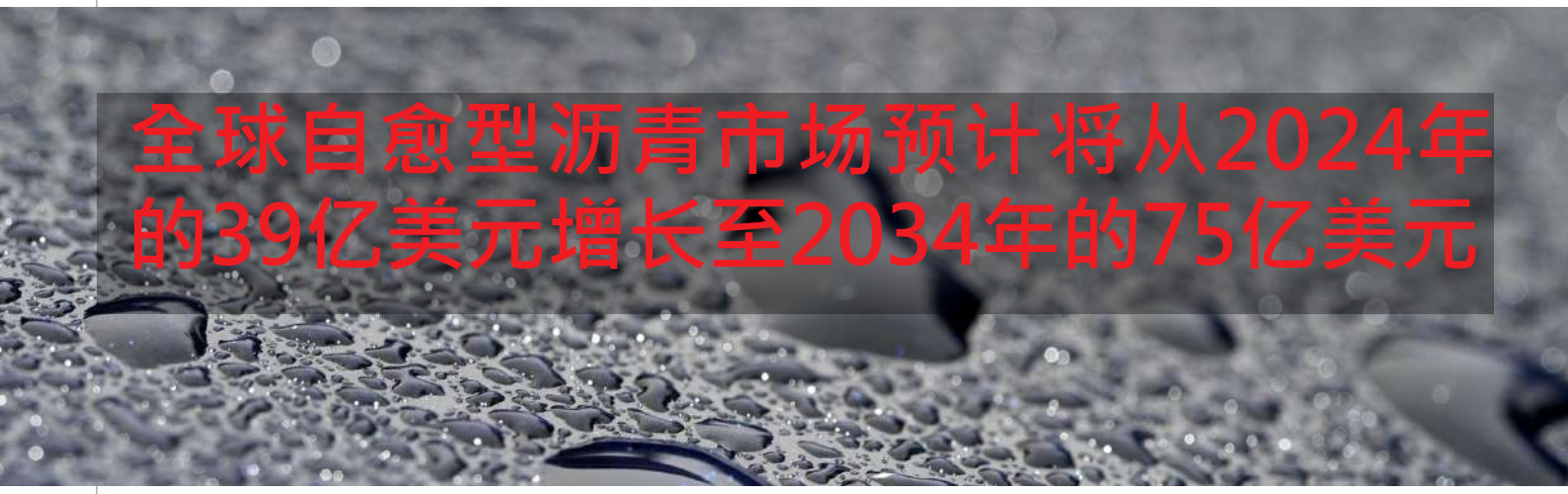
随着森科合同被否决，丹佛市预计将选择报价第二低的供应商——与加拿大森纳维斯能源公司（Cenovus Energy）相关联的Husky Marketing and Supply Co.。该公司将从其位于威斯康星州苏必利尔市或加拿大洛伊德明斯特的炼油厂提供沥青，并通过铁路运输至科罗拉多。

虽然这一选择将使城市每年多花费约6万美元（每吨多约5美元），但议员们认为，为了环保目的，这一价格差异是值得的。与森科不同，森纳维斯表示运往丹佛的沥青将采用传统石油资源炼制，而不是饱受诟病的阿尔伯塔油砂，这种提取方式因其对环境的严重破坏而广受谴责。

森科的设施因污染事故而经常引发公众抗议，包括2016年一次引人注目的黄色烟雾排放事件，该事件引发了紧急警报并激起了居民的恐慌。尽管监管限制使得对该炼油厂——其位置位于丹佛市管辖范围之外——的强制措施受限，但市议员们认为否决合同是一个难得的行动机会。

市议员克里斯·海因兹（Chris Hinds）强调了此次决定的重要性，指出尽管市政府对森科的直接权力有限，但选择其他供应商，即便成本更高、运输时间更长，也是迈向环境责任的重要一步。

这也是丹佛市议会在采购过程中优先考虑道德和环保标准的又一案例，为未来的合同设定了新的先例。



全球自愈型沥青市场预计将从2024年的39亿美元增长至2034年的75亿美元

自愈型沥青行业正迈向大幅扩张，市场价值预计将从2024年的39亿美元几乎翻倍增长至2034年的75亿美元。这一稳定增长由年均复合增长率（CAGR）约6.5%驱动，反映出对更智能、更耐久和更环保的基础设施解决方案的日益增长的需求。

该领域的核心是开发和应用能够自动修复表面损伤的沥青混合物。通过嵌入微胶囊和感应加热系统等先进技术，这些材料旨在延长道路的使用寿命，同时减少维修频率和成本。市场的发展也有助于全球范围内构建更具韧性和可持续性的交通网络。

基础设施耐久性需求推动市场增长

推动市场快速发展的主要因素，是全球对基础设施耐久性和成本效益维护策略的投资不断增加。在新兴技术中，添加微胶囊的自愈型沥青目前处于领先地位，其在延缓路面劣化方面的有效性已得到验证。其次是感应加热型自愈沥青，在大城市中尤其受到欢迎，因为它支持快速高效的养护。

从地域分布来看，欧洲处于领先地位，得益于其对绿色基础设施的高度重视和严格的环保标准。荷兰和德国等国家在研发投入的支持下，正在引领技术进步。北美也发挥着重要作用，美国正在采用创新材料和施工方法，以实现道路现代化。城市发展中减少碳足迹的努力也进一步加快了全球范围内的采用速度。

市场构成与前景

按体积计算，2023年全球自愈型沥青市场约为3亿吨，预计到2033年将增长至5亿吨。道路建设占据最大市场份额，约为45%；其次是公路维护，占30%；城市基础设施项目占25%。随着城市快速扩张，新增道路的强劲需求是道路建设领域占主导地位的关键原因。

在塑造竞争格局的知名企业中，巴斯夫（BASF SE）、壳牌沥青（Shell Bitumen）和拉法基豪西姆（LafargeHolcim）尤为突出。这些公司通过创新、战略联盟和采用尖端技术不断扩展产品线，以保持竞争优势。

监管环境与技术格局

不断演变的监管框架——尤其是在欧盟——对市场动态有重大影响。严格的可持续性法规推动绿色解决方案的采用，同时也影响生产和运营成本。与此同时，技术进步加快，预计未来每年研发支出将增加10%，用于开发更高效、更环保的配方。

人工智能（AI）和物联网（IoT）等新兴技术预计将彻底改变基础设施监测和预测性维护，为智能和自适应道路系统开辟新领域。这些创新，尤其是在智慧城市建设背景下，将为市场增长提供新的空间。

价格趋势与最新进展

自愈型沥青的价格根据所采用聚合物增强配方的复杂程度而有所不同，通常在每吨70至150美元之间。原材料供应的不稳定性以及地区生产能力的差异也会影响成本。聚合物科学的最新突破显著提升了材料的自愈性能，促使越来越多的建筑公司将其作为长期解决方案。

各国政府也在加大对可持续建筑实践的支持，多项基础设施刺激计划中都推广了自修复材料。这些政策预计将在未来五年内推动市场年复合增长率超过10%。此外，科研机构与私营企业之间的合作也在加快生物基聚合物和纳米材料增强沥青的研发，提高材料的环保性与机械强度。

广泛应用的障碍

尽管前景广阔，自愈型沥青市场仍面临一些挑战。其初期生产成本较高，尤其对预算有限的市政部门和承包商构成障碍。此外，由于该技术尚属新颖，许多利益相关者缺乏相关知识或信心，难以从传统沥青过渡。

驱动因素与新兴趋势

构建韧性城市基础设施的紧迫需求是市场扩张的重要推动力。自愈型沥青能够自动修复表面裂缝，契合了减少养护频率与环境破坏的战略目标。

技术进步依旧是行业变革的核心。新型配方中越来越多地引入微胶囊或纤维，在材料受损时释放修复剂，从而延长路面寿命。这一创新不仅契合可持续发展目标，还为传统道路材料提供了具成本效益的替代方案。

智慧城市规划与智能基础设施的融合也在助推市场增长。随着城市中心不断发展，对耐用、低维护道路的需求持续上升——使自愈型沥青成为未来城市生态系统中的关键组成部分。

安装这些材料也需要专业技能，目前尚未广泛普及。此外，不同地区的环境条件对其性能产生影响，使得通用应用面临挑战，亟需本地化适配。监管审批流程冗长复杂，也进一步延缓了市场渗透速度。

未来展望

总体而言，自愈型沥青市场的前景光明，受到环保政策、技术进化和全球向可持续基础设施转型趋势的有力支持。随着研发投资的持续增加，以及对其长期经济效益和环境效益的认识不断加深，该材料的采用有望加速，并彻底改变现代道路的建设和养护方式。

供应与政策的矛盾：中国沥青市场进入施工旺季

2025年1月至4月中国沥青市场分析

AHMAD REZA YOUSEFI – RAZIEH GILANI
INFINITY GALAXY

Ahmad Reza Yousefi 是 Infinity Galaxy 的董事总经理，同时也是国际创业学博士候选人，拥有超过十年的沥青与石化产品出口经验。他带领一支充满热情的团队，致力于通过出口业务促进国家经济发展。他始终专注于与客户建立信任并提供卓越服务。在过去四年中，他持续为客户提供行业动态、市场趋势和深度洞察，帮助他们做出明智的商业决策。

Infinity Galaxy 拥有一支专注于亚洲市场（尤其是印度）的专业团队，致力于为进口商提供定制化支持，协助他们及时高效地进行采购。

Razieh Gilani 是 Infinity Galaxy 的商务副手，在沥青和航运行业拥有超过八年的专业经验。她在非洲、中国、印度和东亚市场的沥青和石化产品贸易及出口方面拥有深厚的专业知识。她已连续 200 多周发布市场分析报告，帮助行业参与者根据最新趋势做出决策。她与一支商业头脑精明的专业团队紧密合作，通过提供深入的见解和战略建议，积极应对市场挑战。

Infinity Galaxy 是一家享有盛誉的沥青与石化产品供应商，在全球市场拥有 10 多年成功经验。我们不仅仅是一个卖家，我们的使命是为客户提供安全、盈利且无忧的采购体验。

为了实现这一目标，我们每周发布市场分析报告，帮助客户在最佳时机、最优条件下做出采购决策。从下订单到货物交付的全过程，我们始终陪伴在您身边，确保整个流程高效、安全、顺畅。

近年来，许多中国公司因从不可靠的供应商处采购而遭受重大损失，反映出中国市场对价格和供应商信誉的高度敏感。Infinity Galaxy 深刻理解中国客户的特殊需求，提供种类齐全、符合标准的优质沥青产品，并根据中国市场提供极具竞争力的价格。

我们的专业支持团队全天候通过微信、阿里巴巴及电子邮件等主流中文平台，为您提供全面服务，确保您的每一笔交易安心无忧。

如果您正在寻找一个值得信赖、专业响应、了解中国市场的长期合作伙伴，Infinity Galaxy 是您明智且安全的选择。

引言

本报告全面分析了2025年1月至4月期间中国沥青市场的动态，重点关注基本面因素、国内与进口价格走势以及主要的经济与地缘政治事件。报告基于Infinity Galaxy的周度分析和Argus沥青价格数据，旨在为行业从业者、出口商、进口商以及政策制定者提供准确、可操作的市场洞察。

市场的基本面因素

2025年前四个月，中国沥青市场受以下三大核心因素影响：

1. 原油和高硫燃料油（HSFO）价格：国际油价波动，尤其是OPEC+的供应政策和政治局势，推动年初沥青价格上涨，3月后有所回落。
2. 季节性需求变化：春节假期与冬季低温使道路和基础设施工程暂停，1月与2月需求显著下降。
3. 中国国内经济政策：尽管政府意图加强基础设施投资，但财政预算拨款延迟与资金紧张，导致多个项目延期或停滞。

中国国内沥青价格走势

- 一月：价格维持在每吨435至450美元之间，市场基本稳定。
- 二月：供应短缺推动价格升至455至470美元区间。
- 三月：库存增加、需求减弱，价格回落至430至445美元。
- 四月：尽管天气改善，但项目活动仍疲软，加上贸易战带来不确定性，价格在420至440美元之间波动，部分低至415美元。

中国沥青进口价格走势

- 一月：CFR中国东部港口报价约为430至435美元。
- 二月：受亚洲区域供应减少影响，价格升至470美元左右。
- 三月：进口价格回落至430至450美元，与国内价格趋于一致。
- 四月：在需求疲软与贸易不确定性影响下，价格维持在420至445美元之间，个别交易低于420美元。

关键事件及其市场影响

- 春节假期：1月至2月项目暂停，需求短期下降。
- 亚洲炼厂检修：2月新加坡与韩国供应减少，推高进口报价。
- 财政预算延迟：政府未及时拨款，许多地方工程延期。
- 特朗普关税政策：2025年4月2日，美国政府宣布新一轮关税，标志着中美贸易战爆发。该政策影响能源与原材料产品，包括沥青，引发市场避险情绪，抑制进口决策，打击贸易平衡与价格预期。

结论

2025年前四个月，中国沥青市场受季节、宏观经济与地缘政治多重因素影响，价格出现阶段性波动。尽管长期基础设施投资前景乐观，但国际贸易摩擦与资金不足等问题，成为市场恢复的不确定因素。进入5月后，随着施工季逐步展开，预计市场需求温和回升。市场能否稳定增长，仍取决于中美贸易关系进展、政府资金支持情况以及亚洲主要供应国的出口策略。

报告日期：2025年05月26日

政府支持的克里比沥青项目将于2025年启动建设阶段

据WPB报道，喀麦隆克里比新建沥青生产设施的建设工作预计将于2025年启动，并获得国家政府的大力支持。

2025年4月29日，代理矿业、工业与技术发展部长前往该项目的预定施工地点进行实地视察。该地点位于南部大区克里比工业-港口区内。此次视察凸显了政府对该项目的承诺，该项目由本地公司 All Bitumen Plc 主导实施。

All Bitumen Plc 的首席执行官艾哈迈杜·奥马鲁（Ahmadou Oumarou）确认，领导该项目的政府跨部门监督机构负责人——富·卡利斯图斯·詹特里（Fuh Calistus Gentry）部长在现场再次重申了政府对项目的坚定支持。奥马鲁表示，部长特别强调愿为投资者提供一切必要协助，尤其是那些规划完善、影响深远的项目。

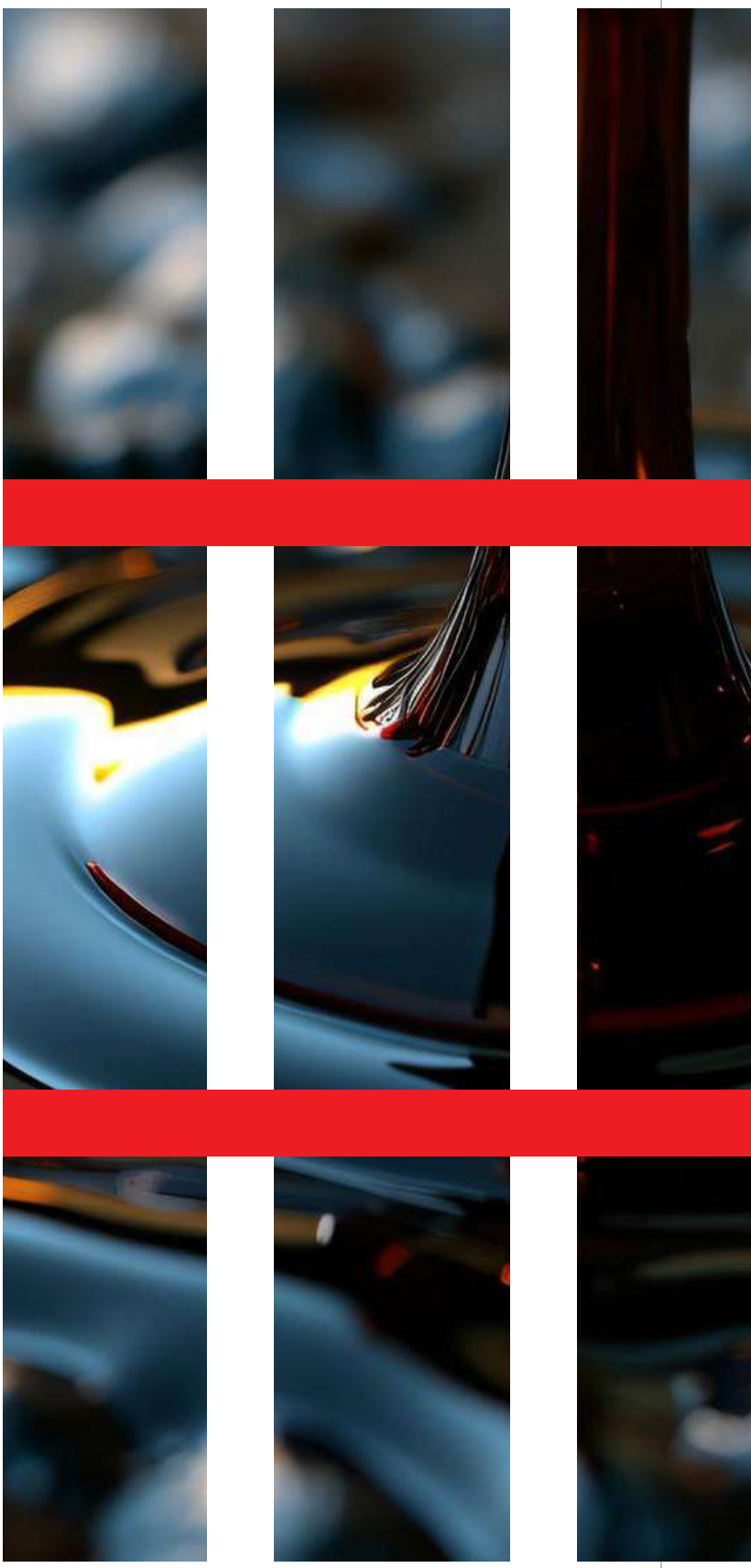
在施工现场，詹特里部长审查了中国港湾工程有限责任公司（CHEC）开展的初期准备工作。自2025年3月20日起，CHEC 已对60公顷项目地块进行了清理。All Bitumen Plc 已聘请该公司承担前期工程，后续大规模的土方作业与建设活动将于年内晚些时候启动。

该项目总投资预计为1610亿中非法郎。部分资金将由非洲进出口银行（Afreximbank）提供，该行已于2024年底与 All Bitumen Plc 签署了融资主承协议。作为牵头安排人，Afreximbank 不仅将出资，还将协调其他投资合作方的参与。

新设施将配备一个日处理能力为10,000桶原油的小型炼油厂，用于供应年产25万吨沥青的原材料。

基础设施专家预计，该项目将使喀麦隆的道路建设成本降低多达30%。此外，项目还将直接创造300至400个就业岗位，并带动约1500个间接就业机会。

德国于2025年更新道路沥青技术标准



据WPB报道，德国道路与交通研究协会（FGSV）已发布《2025年道路沥青及即用型聚合物改性沥青技术交付条件》新版标准。本次更新的一大亮点是首次将“超软型”道路沥青纳入官方规范。

该修订文件名为 TL Bitumen-StB 25，规定了用于热拌沥青混合料中的沥青在道路、人行道及其他铺装交通表面的供应与使用条件。它取代了此前于2007年发布、2013年修订的旧版标准。

新标准依据以下两项重要欧洲标准，纳入了德国的国家级技术要求：

DIN EN 12591：用于常规道路施工的铺路级沥青标准；

DIN EN 14023：界定聚合物改性沥青（PmB）性能的标准，该类沥青通过聚合物增强，以提高柔性和抗变形能力。

此外，此次修订还整合了德国联邦交通部于2019年发布的道路建设通用通报（ARS 8/2019）中的关键修正内容，并吸收了研究项目 FE 29.0459/2020 的成果。该项目主要评估沥青结合料（即含添加剂的沥青）在实验室人工老化条件下的性能变化。

基于此，TL Bitumen-StB 25 增加了关于流变性能（即材料在不同应力或温度变化下的流动与行为特性）的新要求，这对于确保路面持久性与行车安全性至关重要。

该文件编号为 794，由FGSV正式发布，面向科研人员、工程师及相关机构开放获取。有关该文件的获取方式可通过FGSV官方渠道查询。

Chevron, Shell, and BP Strengthen LNG Presence in Egypt Amid Global Energy Shifts

According to WPB, global energy giants Chevron, Shell, and BP are intensifying their involvement in Egypt's natural gas sector, positioning the country as a critical hub for liquefied natural gas (LNG) in a rapidly evolving geopolitical and energy landscape.

The conflict in Eastern Europe significantly disrupted traditional

energy supply routes, particularly from Russia to Europe, prompting a major shift in global LNG strategies. As Western nations sought to reduce their reliance on Russian resources, LNG emerged as a flexible and strategic alternative, capable of being traded globally without the infrastructural and political limitations of pipelines. This surge in demand repositioned Egypt as a focal point due to its operational LNG export facilities and strategic control

over key transit routes, notably the Suez Canal and the Suez-Mediterranean Pipeline.

Major international players have moved quickly to capitalize on Egypt's advantages. Chevron has recently been highlighted in local media for expected new exploration rights in the northeastern Mediterranean, following previous discoveries near the Sinai Peninsula, including the promising Nargis-1 well. Chevron also maintains operations in nearby energy-rich zones such as Israel's Leviathan and Tamar fields, and Cyprus's Aphrodite project.

Egypt's geographic position further amplifies its importance.

Shell has commenced development of the tenth phase of the West Delta Deep Marine concession in the Mediterranean, while BP has committed approximately $3.5 billion to further exploration and development efforts in Egypt over the coming years. This figure could increase substantially if new reserves are uncovered. With an estimated 1.8 trillion cubic meters of gas — a figure considered conservative by European energy analysts — Egypt's resource potential remains significant. Industry research firm Wood Mackenzie values the undeveloped fields in the Eastern Mediterranean at around $19 billion.

Egypt's geographic position further amplifies its importance. As the only Eastern Mediterranean country with functioning LNG export terminals, it supports the West's broader strategy to enhance global LNG supply chains. Control over the Suez Canal — through which roughly 10% of global oil and gas shipments pass — offers an additional logistical edge.

The Suez-Mediterranean Pipeline also serves as a vital alternative for oil transport between the Persian Gulf and the Mediterranean.

In contrast to other strategic maritime passages such as the Strait of Hormuz or the Bab al-Mandab Strait, both under growing Chinese influence through strategic alliances and infrastructure investments, Egypt's transit routes remain independent, making them crucial assets for Western energy security planning.

From a geopolitical standpoint, Egypt continues to hold a central role in the Arab world. Historically viewed as a leader in pan-Arab unity and regional cooperation, its alignment with Western interests carries both symbolic and strategic weight. This alignment is seen as particularly valuable in light of the shifting alliances in the Middle East, notably the closer ties between Saudi Arabia and the China-Russia axis.

Western support for Egypt's LNG ambitions has also included economic assistance aimed at managing the financial strain caused by rapid energy sector development. According to a senior EU energy official, Egypt's capacity to meet its debt obligations to Western developers has declined, but coordinated financial relief measures have been implemented. One such measure is the expansion of Egypt's financial support program with the International Monetary Fund, which recently enabled access to an additional $1.2 billion. Further aid remains available from institutions such as the World Bank and the European Union.

As Egypt deepens its role in global LNG supply chains, its strategic relevance — both economically and geopolitically — is likely to increase, making it a key player in the energy dynamics of the coming years.

Investigating the Mechanical and Chemical Characteristics of Bitumen through Accelerated Chromatographic Fractionation

According to WPB, recent advancements in bitumen analysis have brought forward a novel and efficient methodology for separating its core components. Bitumen, a dense and multifaceted by-product of petroleum refining, is a fundamental material in road construction. Its durability and functional properties are inherently connected to its internal composition, which includes four primary groups: saturates, aromatics, resins, and asphaltenes—collectively known as SARA. Traditional separation techniques, while widely used, often suffer from extended processing durations, limited efficiency, and suboptimal sample recovery.

To address these challenges, Hallmark-Haack and colleagues have introduced an enhanced technique based on automated flash chromatography. This modern approach aims to refine the fractionation process, enabling more precise and faster isolation of bitumen's chemical groups. Such improvements are particularly vital for the asphalt sector, where a clear understanding of each fraction's characteristics can directly influence the quality, resilience, and sustainability of pavement materials.

Hallmark-Haack and colleagues

In their experimental framework, the researchers tested four commercially available chromatography columns, each containing a distinct stationary phase, to evaluate their performance in isolating bitumen's molecular groups. The goal was to determine which column provided the best balance between resolution, processing speed, and sample integrity. The comparative analysis

emphasized efficiency in separation, the amount of material recovered, and the clarity of analytical outcomes.

Among the various columns, the C18 type emerged as the most proficient in delivering a clear, high-resolution fractionation. This column facilitated a more detailed exploration of bitumen's molecular architecture, allowing researchers to pinpoint the individual roles of each component in influencing the material's overall behavior. The compatibility of the C18 column with bitumen's intricate chemical matrix highlighted the importance of carefully selecting chromatographic tools that align with the unique attributes of complex samples.

Following separation, the individual fractions were subjected to a comprehensive battery of tests. These included both analytical chemistry procedures and rheological assessments, designed to measure the chemical composition and mechanical responses of each group under different environmental conditions. By integrating these two analytical dimensions, the researchers were able to construct a thorough understanding of how each component contributes to bitumen's performance, particularly under thermal variation and mechanical stress.

"The goal was to determine which column provided the best balance between resolution, processing speed, and sample integrity.

The implications of this study are substantial for the pavement and construction industries. The adoption of time-saving flash chromatography enables a more effective quality control process, paving the way for bituminous materials that are both more durable and economically viable. This technique not only enhances the efficiency of laboratory workflows but also supports broader objectives related to sustainable infrastructure and long-term performance optimization.

In summary, the investigation led by Hallmark-Haack et al. represents a meaningful advancement in bitumen characterization.

Their deployment of flash chromatography addresses the shortcomings of conventional methods and offers a reliable alternative for dissecting bitumen's complex chemistry. Beyond its immediate practical benefits, the study establishes a foundation for ongoing research into the interplay between chemical structure and material behavior, ultimately contributing to the evolution of asphalt technology and infrastructure engineering.

CMA CGM RESTRUCTURES FLEET STRATEGY TO BYPASS U.S. CHARGES ON CHINESE-MADE SHIPS

According to WPB, French maritime giant CMA CGM has decided to reorganize the deployment of its vessels across global routes in an effort to sidestep upcoming U.S. port tariffs targeting ships manufactured in China. The financial chief of the company, Ramon Fernandez, explained that this strategy is a direct response to the anticipated levies which will be implemented in the near future.

These new port charges present an additional challenge for international shipping companies already coping with the repercussions of ongoing U.S. trade policies. However, Fernandez noted that recent modifications by U.S. authorities, following strong opposition from industry players, have made the fee structure less severe than initially anticipated.

The U.S. administration has introduced the tariffs as a countermeasure to China's dominance in the shipbuilding sector, aiming to encourage a resurgence in America's maritime capabilities. CMA CGM, the world's third-largest container carrier, intends to leverage its existing fleet capacity to mitigate the financial impact of these charges. According to Fernandez, fewer than 50% of the company's approximately 670 ships were constructed in China, which allows room for strategic adjustments.

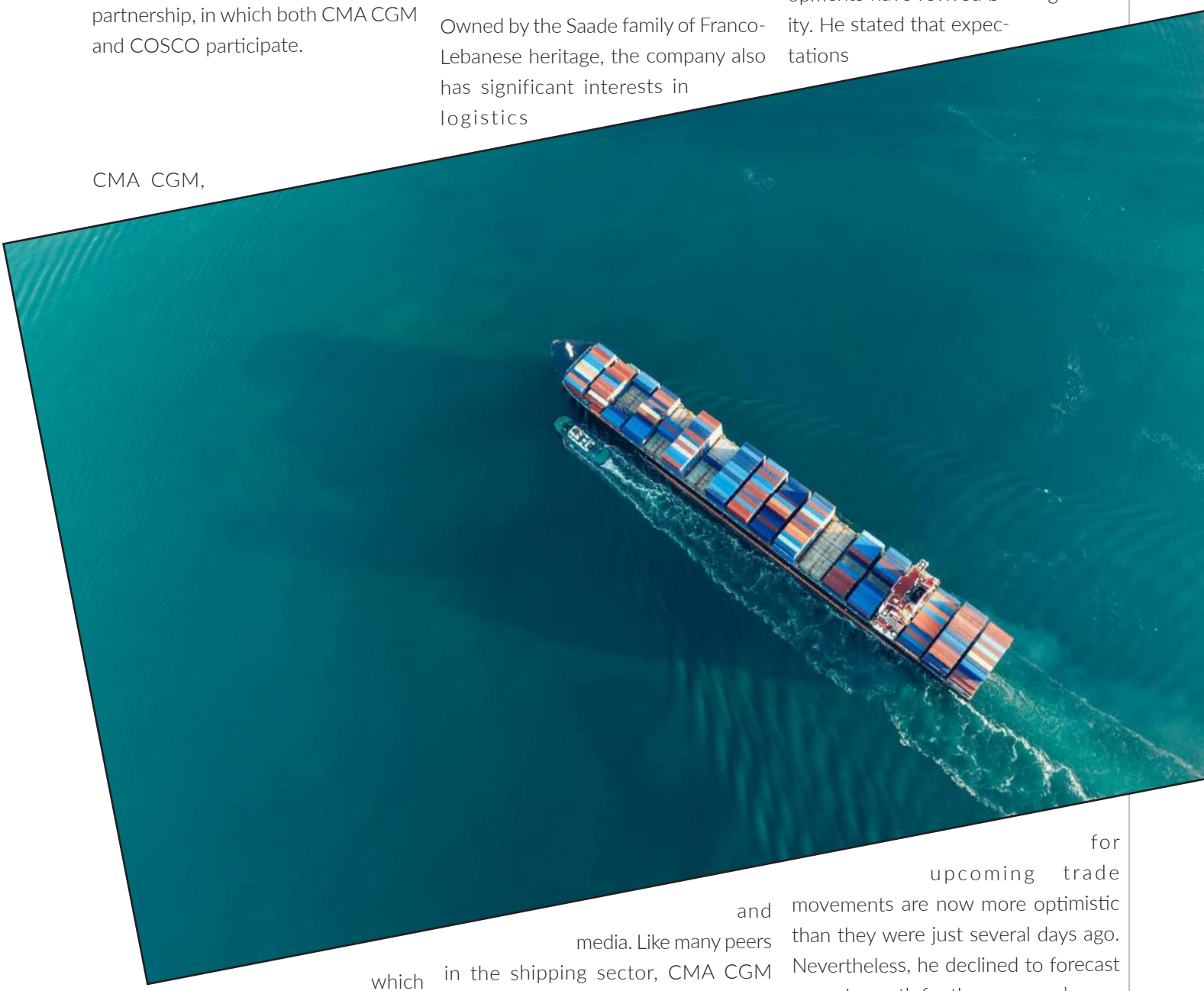
根据《WPB》报道，法国航运巨头达飞海运集团（CMA CGM）决定重新调整其船只在全球航线的部署，以规避即将实施的美国港口关税，这些关税将针对中国制造的船只。公司首席财务官拉蒙·费尔南德斯（Ramon Fernandez）表示，这一策略是对即将实施的关税的直接回应。

Under the new U.S. fee framework, ships both built and operated by Chinese companies will incur the highest charges when docking at American ports. Despite these penalties, Fernandez expressed confidence that shipping lines—including China's COSCO—will adapt accordingly. He refrained from discussing how the new policy might affect the Ocean Alliance partnership, in which both CMA CGM and COSCO participate.

CMA CGM, which received praise from the U.S. government for announcing a $20 billion investment in American infrastructure, reported solid growth in its latest quarterly performance. A preemptive surge in shipments, driven by the looming U.S. tariff announcement, contributed to a 4.2% year-on-year increase in transport volumes, boosting the group's overall revenue and earnings.

Owned by the Saade family of Franco-Lebanese heritage, the company also has significant interests in logistics and media. Like many peers in the shipping sector, CMA CGM observed a sharp decline in trade activity between China and the U.S. following a tariff escalation, before seeing a rebound due to a temporary agreement between the two countries to ease trade restrictions.

Fernandez confirmed that nearly half of the scheduled shipments for the China-U.S. route were canceled earlier in the season, although recent developments have revived booking activity. He stated that expectations for upcoming trade movements are now more optimistic than they were just several days ago. Nevertheless, he declined to forecast annual growth for the company's container operations, pointing to continued uncertainty surrounding the fluctuating trade landscape.



Shaping a Sustainable Industry: The Evolution of Base Oil Technologies for a Low-Carbon Future

According to WPB, the role of base oils in modern energy and industrial systems has reached new levels of importance. As global industries work toward sustainability and strive to reduce their carbon footprint, innovations in base oil technology are becoming central to meeting both environmental and performance objectives.

This evolution extends beyond merely complying with regulations—it represents a proactive shift toward long-term efficiency, cost-effectiveness, and environmental responsibility. With significant progress in synthetic lubricants, bio-based alternatives, and digital integration, the base oil sector is entering a new phase of innovation.

Toward Low-Carbon Lubrication: New Formulations and Cleaner Processes

Progress in base oil production is increasingly defined by the development of low-carbon solutions. These include advanced refining techniques that reduce greenhouse gas emissions and a shift toward renewable feedstocks. Hydroprocessing technologies—particularly hydrocracking and hydrotreating—have been enhanced to use cleaner energy inputs and optimized catalysts, leading to base oils with superior thermal stability and lower environmental impact.

A major breakthrough in this area is the advancement of bio-based base oils. Sourced from renewable materials such as vegetable oils and animal fats, they present a biodegradable and low-emission alternative to conventional mineral oils. Their application is growing rapidly in areas sensitive to environmental risk.

Equally impactful are re-refined base oils, which are created by processing used lubricants. These recycled oils now offer comparable quality to virgin products, thanks to improvements in vacuum distillation and hydrotreating. This innovation promotes circular economy practices and minimizes waste.

Additives Engineered for Sustainability

Modern additives are being re-engineered to match the low-carbon priorities of contemporary lubricants. These formulations are designed not only to protect and enhance the performance of machinery but also to cut down emissions and fuel use.

Friction modifiers now leverage advanced chemistries to reduce energy loss between moving parts, significantly improving fuel efficiency and cutting CO_2 emissions. Similarly, detergents and dispersants are optimized to ensure cleaner combustion and longer engine life, while newer anti-wear compounds eliminate toxic components such as chlorine or heavy metals without sacrificing protection.

The Strategic Rise of Synthetic Lubricants

Synthetic lubricants have become indispensable in supporting low-carbon initiatives. Developed through controlled chemical processes, these lubricants offer superior molecular uniformity, resulting in minimized friction, better temperature stability, and lower volatility.

In automotive systems, synthetic oils perform reliably under extreme conditions, helping reduce energy loss and prolonging engine life. They also improve fuel economy and lower overall emissions.

Their value is even more evident in electric vehicles, which require efficient thermal management and specific dielectric properties. Synthetic lubricants are tailored to meet these needs, increasing EV range and energy performance while reducing lifecycle emissions.

Driving Sustainability in Industrial Applications

High-performance lubricants are essential in maintaining operational continuity across industries. Synthetic options stand out in sectors such as manufacturing, aerospace, and renewable energy, where they reduce downtime, extend service intervals, and minimize environmental impact.

For instance, in wind turbines, synthetic oils ensure functionality under intense stress and weather conditions, aiding the transition toward renewable energy. In manufacturing, they optimize machinery performance while reducing energy waste.

One of their key environmental advantages is their extended service life. Less frequent oil changes mean reduced waste and lower overall resource consumption, aligning with sustainability targets and delivering long-term cost benefits.

Market Transformation and Strategic Positioning

The implementation of low-carbon base oil solutions is increasingly seen as a strategic investment. As markets grow more eco-conscious, companies adopting sustainable lubricants gain a competitive advantage. Certification schemes, governmental incentives, and rising consumer awareness are accelerating this trend.

Driving Sustainability in Industrial Applications

These technologies are being recognized not only for their ecological advantages but also for their contribution to operational efficiency. Forward-looking manufacturers are leveraging these benefits to enhance their brand reputation and future-proof their operations.

Integrating Smart Technologies: The Rise of Digital Lubrication

Digital innovation is redefining how lubricants are monitored and utilized. With smart sensors embedded in lubrication systems, real-time performance tracking and predictive maintenance are now possible. These capabilities help optimize lubricant usage, prevent machinery failures, and reduce overall waste.

The integration of data analytics and IoT within lubrication practices further enhances energy efficiency and extends equipment lifespan, contributing to

Collaborative Innovation and Research-Driven Progress

The momentum behind these advancements is supported by cross-sector collaboration. Partnerships among manufacturers, universities, and research institutions are enabling the development of pioneering solutions—such as bio-catalysts for converting unconventional materials like algae into base oils, or nanotechnology-based additives that operate at the microscopic level to reduce friction and wear.

These cooperative efforts are accelerating the industry's shift toward a sustainable model while expanding its capacity for rapid technological integration.

A New Standard for Lubrication Technology

In this era of transformation, Group II and Group III hydroprocessed base oils have become foundational due to their high purity and excellent performance. Simultaneously, bio-based and synthetic options are carving out substantial roles in both traditional and emerging applications.

Synthetic base oils—including PAOs and esters—remain crucial for demanding environments, and efforts to improve their environmental footprint are making them more accessible and responsible. Their use in EVs is expanding rapidly, reflecting the growing need for specialized lubricants in an electrified world.

Complementing these formulations, low-carbon additives are now an essential part of lubricant innovation, ensuring compliance with global sustainability objectives while maximizing performance.

The Road Ahead: Toward a Greener Industrial Ecosystem

As the lubricant industry continues to align with environmental imperatives, its path forward is being shaped by a blend of innovation, digitalization, and cross-industry collaboration. Producers are responding not only to regulatory changes but also to the broader call for corporate responsibility and efficiency.

By investing in low-carbon technologies, smart systems, and sustainable production methods, the base oil sector is redefining its role in modern industry. These advancements are not just technical achievements—they are building blocks for a cleaner, more resilient, and high-performing future.

Aramid Fiber Integration: A Step Forward in Pavement Durability and Environmental Efficiency

According to WPB, recent evaluations of multiple infrastructure projects demonstrate the powerful impact of aramid fiber reinforcement in boosting asphalt pavement performance while promoting sustainability. This approach, tested and reviewed by Kindler and Associates Engineering through advanced analysis tools including ASTM D 6433 standards and the PAVER Pavement Management System, is gaining recognition for its capacity to enhance structural reliability, reduce long-term maintenance expenses, and prolong service life.

Strengthening Infrastructure: Three Practical Examples

Public infrastructure authorities continually seek innovative strategies to extend the lifespan and strength of roadways. One such innovation—aramid fiber reinforcement—is delivering promising results across various applications. Three evaluated road sections from Pennsylvania and Maryland present valuable insights into its effectiveness.

Project Review 1: Clearfield County, Pennsylvania

On a section of SR 4014 Rockton Road, an experimental overlay using aramid fiber-reinforced warm-mix asphalt was placed alongside a standard mix for comparative analysis. The reinforced overlay, consisting of a 9.5-mm surface layer installed to a depth of 1.5 inches, showed significant durability over time.

When re-evaluated years later, the fiber-reinforced section maintained a high Pavement Condition Index (PCI) of 92.3, displaying only mild surface weathering and cracking with no signs of rutting. In contrast, the conventional section, which had been chip-sealed, presented a PCI of 87.6. Joe Kindler, Sr., P.E., an expert with decades of experience in pavement assessments, anticipates that the reinforced overlay will preserve its solid condition well beyond the non-reinforced segment.

Project Review 2: Tyburn Road, Bucks County, Pennsylvania

Another comprehensive application occurred along SR 2020 Tyburn Road, where aramid fibers were incorporated throughout all pavement layers to support heavy industrial traffic. This roadway was engineered to endure over 30 mil-

lion Equivalent Single Axle Loads (ESALs), with nearly half of the volume comprising large vehicles such as waste transporters and freight trucks.

Long-term monitoring of this route revealed outstanding performance. The westbound and eastbound sections recorded PCI scores of 85.7 and 86.1, respectively, with only minimal deterioration—an annual decline of just 1.5 points. The primary issue observed was limited centerline joint cracking, easily addressed through standard maintenance procedures. By comparison, older nearby segments lacking reinforcement, constructed one to two decades earlier, had degraded to an average PCI of 49, with much steeper deterioration rates.

Project Review 3: US Route 40, Washington County, Maryland

A multi-section trial along this route contrasted aramid fiber-reinforced asphalt with a premium gap-graded mix used by the Maryland State Highway Administration. The test aimed to assess cost-effectiveness and performance under similar conditions.

Later evaluations showed that the aramid fiber segments achieved a PCI of 86.3, marginally surpassing the 85.4 PCI of the premium mix. While the gap-graded mix exhibited early surface raveling and wider cracking near stress points, the fiber-reinforced areas remained more intact, indicating superior surface resilience. Moreover, the aramid blend achieved these outcomes at a lower overall cost.

Environmental and Economic Implications

The long-term data collected from these projects emphasize the practical benefits of aramid fiber reinforcement, especially in terms of sustainability. Lower degradation rates, reduced need for repair, and longer pavement life result in fewer resource demands and lower carbon emissions. From a financial standpoint, fewer maintenance cycles translate to reduced life-cycle expenditures.

Overall, findings from SR 4014, Tyburn Road, and US Route 40 offer compelling evidence in favor of integrating aramid fibers into asphalt mix designs. Their inclusion not only bolsters performance metrics like PCI scores but also supports broader environmental and economic goals for infrastructure development.

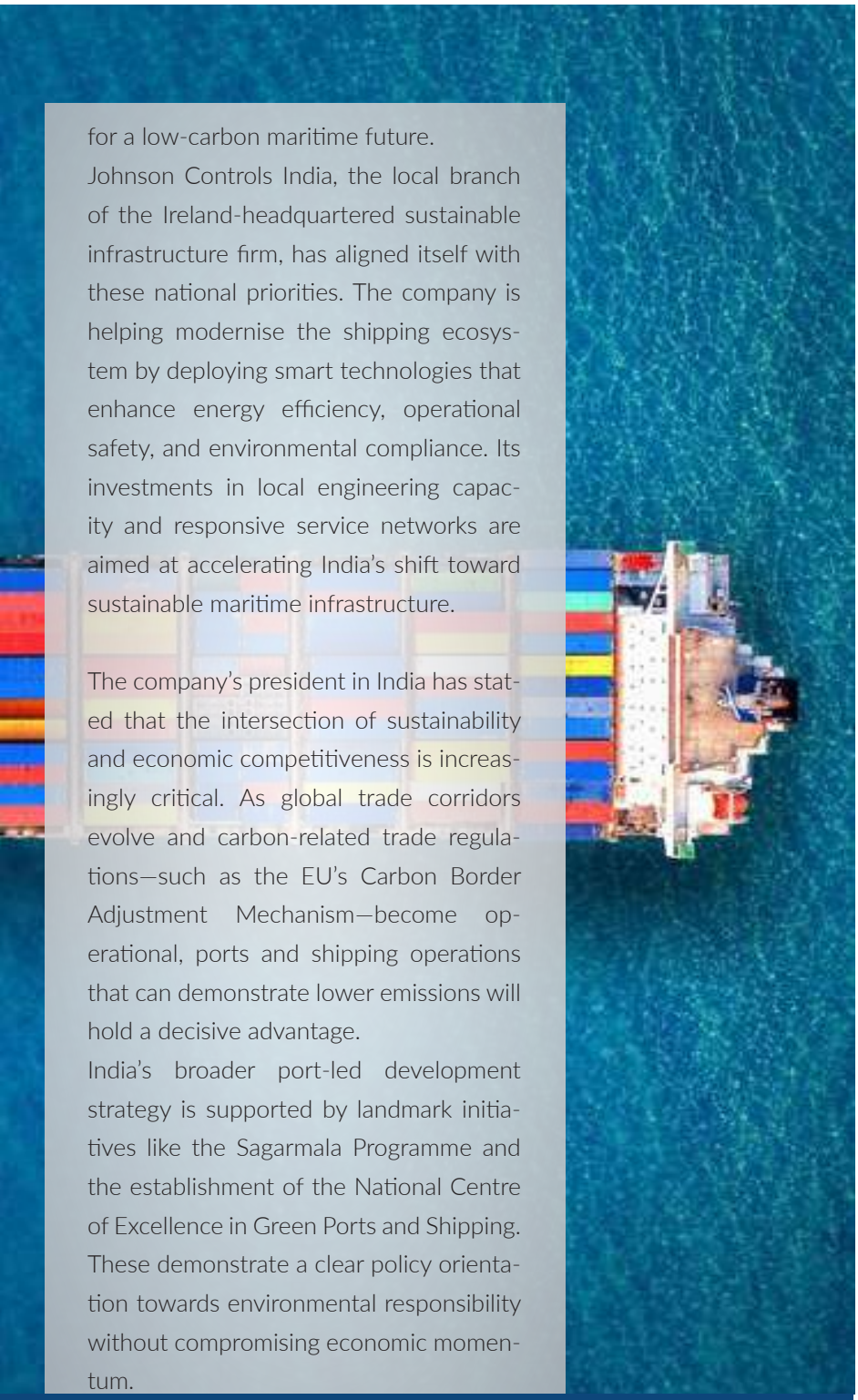
Green Shipping

India's Green Shipping Gains Strategic Momentum

By Bitumenmag

According to WPB, India's maritime sector is entering a critical phase where environmental sustainability is no longer a peripheral goal but a strategic imperative. This transformation is being shaped not only by government-led policies but also by the contributions of global infrastructure leaders such as Johnson Controls, which is actively working with Indian maritime stakeholders to drive the transition toward greener and more efficient operations.

The Indian government has launched a series of initiatives aimed at reducing emissions across its shipping and port infrastructure. These include the formation of a Rs 25,000 crore Maritime Development Fund to boost green investment, as well as programs such as the Green Tug Transition and Harit Nauka (Green Vessel), which are designed to promote decarbonisation. Measures like shore-power integration and green hydrogen hubs further reinforce India's vision



for a low-carbon maritime future.

Johnson Controls India, the local branch of the Ireland-headquartered sustainable infrastructure firm, has aligned itself with these national priorities. The company is helping modernise the shipping ecosystem by deploying smart technologies that enhance energy efficiency, operational safety, and environmental compliance. Its investments in local engineering capacity and responsive service networks are aimed at accelerating India's shift toward sustainable maritime infrastructure.

The company's president in India has stated that the intersection of sustainability and economic competitiveness is increasingly critical. As global trade corridors evolve and carbon-related trade regulations—such as the EU's Carbon Border Adjustment Mechanism—become operational, ports and shipping operations that can demonstrate lower emissions will hold a decisive advantage.

India's broader port-led development strategy is supported by landmark initiatives like the Sagarmala Programme and the establishment of the National Centre of Excellence in Green Ports and Shipping. These demonstrate a clear policy orientation towards environmental responsibility without compromising economic momentum.

However, challenges persist. A large portion of the national fleet comprises aging vessels that are not equipped to meet upcoming environmental norms. Retrofitting such ships with alternative fuel engines or energy-saving systems requires significant capital investment, often with delayed returns that discourage private stakeholders.

Another obstacle is the limited availability of infrastructure for green fuels—such as bunkering facilities for LNG or hydrogen—hindering rapid adoption. Furthermore, aligning domestic regulations with international standards, especially those set by the International Maritime Organisation (IMO), requires regulatory reform and greater incentives for the private sector.

Johnson Controls has pointed out that bridging the gap between policy and execution is essential for fostering innovation and long-term transformation. The company continues to collaborate with both government bodies and private operators to develop scalable, future-ready solutions for maritime infrastructure.

Complicating this transition is the volatile nature of global trade, shaped by geopolitical disruptions that affect shipping routes, fuel prices, and logistical operations. In such an environment, India must carefully navigate the interplay between sustainable development, economic priorities, and international competitiveness.

Creating a coherent framework that supports green innovation, de-risks investment, and delivers practical regulatory guidance will be crucial in making India a resilient and sustainable maritime hub for the future.

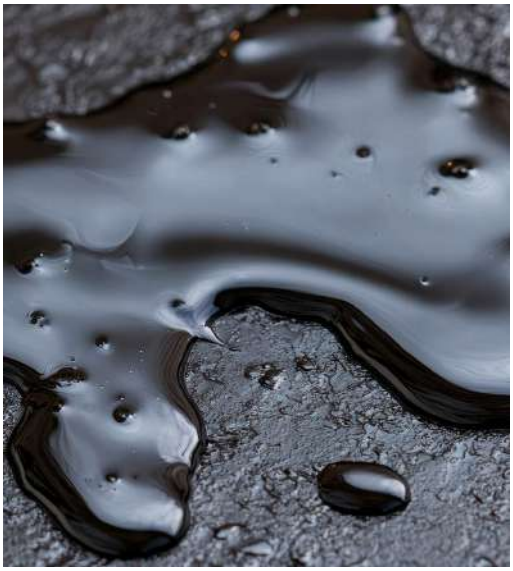
BITUMEN ON THE ROAD TO SUSTAINABILITY AND INNOVATION

According to WPB, the familiar black asphalt under our tires — held together by bitumen — faces a future crossroads. As the world steadily moves away from fossil fuels, industries must confront a pressing challenge: how to maintain and build roads without relying on petroleum-derived materials. Bitumen, once a residual waste from oil refining, has evolved into an indispensable product in road construction. Yet, the need for sustainable, climate-friendly solutions is driving innovation across the sector.

Bitumen's role is both essential and problematic. Each ton of asphalt contains around 50 kilograms of bitumen, which acts as the binder holding the aggregate together. One of its advantages is that

it can be re-melted at temperatures above 150°C, making recycling theoretically easier than with cement-based materials. But the material has a hidden weakness: over time, it ages. Under the effects of sunlight, air, and high temperatures, some of bitumen's thousands of chemical components evaporate or transform, leaving it brittle and less effective at bonding the asphalt mix.

This aging means that when old road material is reused, it must be supplemented with fresh bitumen or special rejuvenators designed to restore flexibility and adhesion. The market already offers numerous rejuvenating products, some derived from renewable raw materials, opening the door to more sustainable recycling practices.

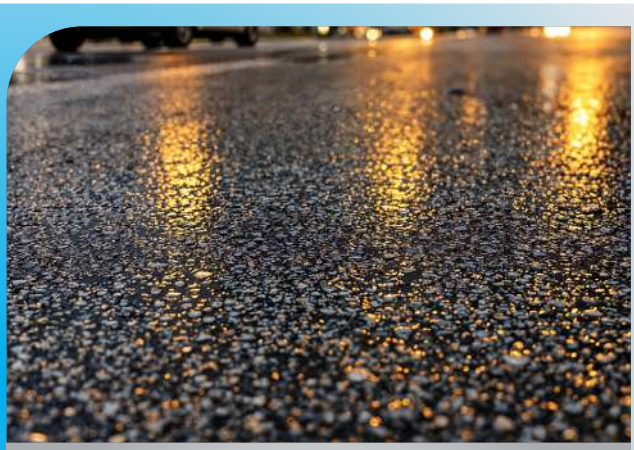


In countries like Switzerland, where roads are more often rehabilitated than newly built, recycling has become an attractive path forward. Asphalt researcher Martins Zaumanis from Empa in Dübendorf points out that significant recycling potential lies hidden in existing road surfaces — but it's not fully tapped. Currently, recycling is common in the lower layers of a road, yet the top layers, which face the most wear, still mostly rely on virgin materials.

Promising experiments are already underway. For example, a test section in Uster, near Zurich, was constructed

with a surface layer containing nearly one-third reclaimed asphalt. Meanwhile, on the Lukmanier Pass, connecting the regions of Graubünden and Ticino, researchers pushed the recycling rate in the lower layers up to 85%, using tall oil (a byproduct of the paper industry) as a rejuvenator. These high-recycling pavements, despite facing heavy traffic and harsh weather, are reportedly performing as well or even better than conventional roads.

Environmental impact is a central concern. Producing asphalt releases significant CO2 — about 50 kilograms per ton — mainly due to the extraction and heating of bitumen and aggregates. Extending the lifespan of roads thus plays a crucial role in reducing the overall carbon footprint. Chemist Hinrich Grothe from the Technical University of Vienna is investigating how bitumen's aging process itself contributes to emissions. Using a combination of spectroscopic analysis and mechanical tests, Grothe's team aims to reveal how chemical changes alter the material's



properties over time.

The search for sustainable alternatives has also led to major collaborative projects. One such effort, the Nobit project (short for "No Bitumen"), has secured over €700,000 in funding. Led by asphalt expert Michael Wistuba from the Technical University of Braunschweig, the initiative aims to develop systematic testing methods and design strategies for creating high-performance asphalts from recycled and plant-based materials. From 2026 onward, test sections — ideally at least one kilometer long — will be laid, potentially on highways, to trial these innovative mixes.

Several bio-based additives are under examination. Among them are modified vegetable oils from Cargill, plant resins from the plastics company Kraton, and rejuvenators made from the caustic liquid found in cashew nut shells, supplied by the Dutch company Ventraco. While some of these products have already gained attention — such as the "biobitumen" offered by German startup B2Square, which integrates cashew-shell derivatives — questions remain regarding the sourcing of fossil components in these mixtures and whether the label "bio" truly applies.

Meanwhile, researchers and engineers in Basel are exploring yet another approach: incorporating biochar — a carbon-rich material similar to charcoal — into asphalt. Produced from green waste at high temperatures under low-oxygen conditions, biochar offers a way to lock carbon dioxide directly into road surfaces. For every ton of biochar-infused asphalt, approximately 50 kilograms of CO2 can be sequestered. Early tests also suggest performance benefits, with improved resistance to rutting compared to conventional asphalt.

Although these biochar-enhanced mixes have so far only been applied to the thicker, less stressed lower asphalt layers, the potential remains significant. Pilot installations are currently being monitored both in quiet residential streets and on heavily used truck routes in the Basel region. Even neighboring areas have launched their own trials.

The long-term results of these pilot projects will be crucial. Only with time and real-world data can the road construction sector determine whether these innovations will allow roads to shift from being climate burdens to becoming active contributors to climate solutions. By combining advanced recycling, bio-based additives, and carbon-sequestering technologies, the industry may be paving the way — quite literally — toward a more sustainable and resilient infrastructure future.

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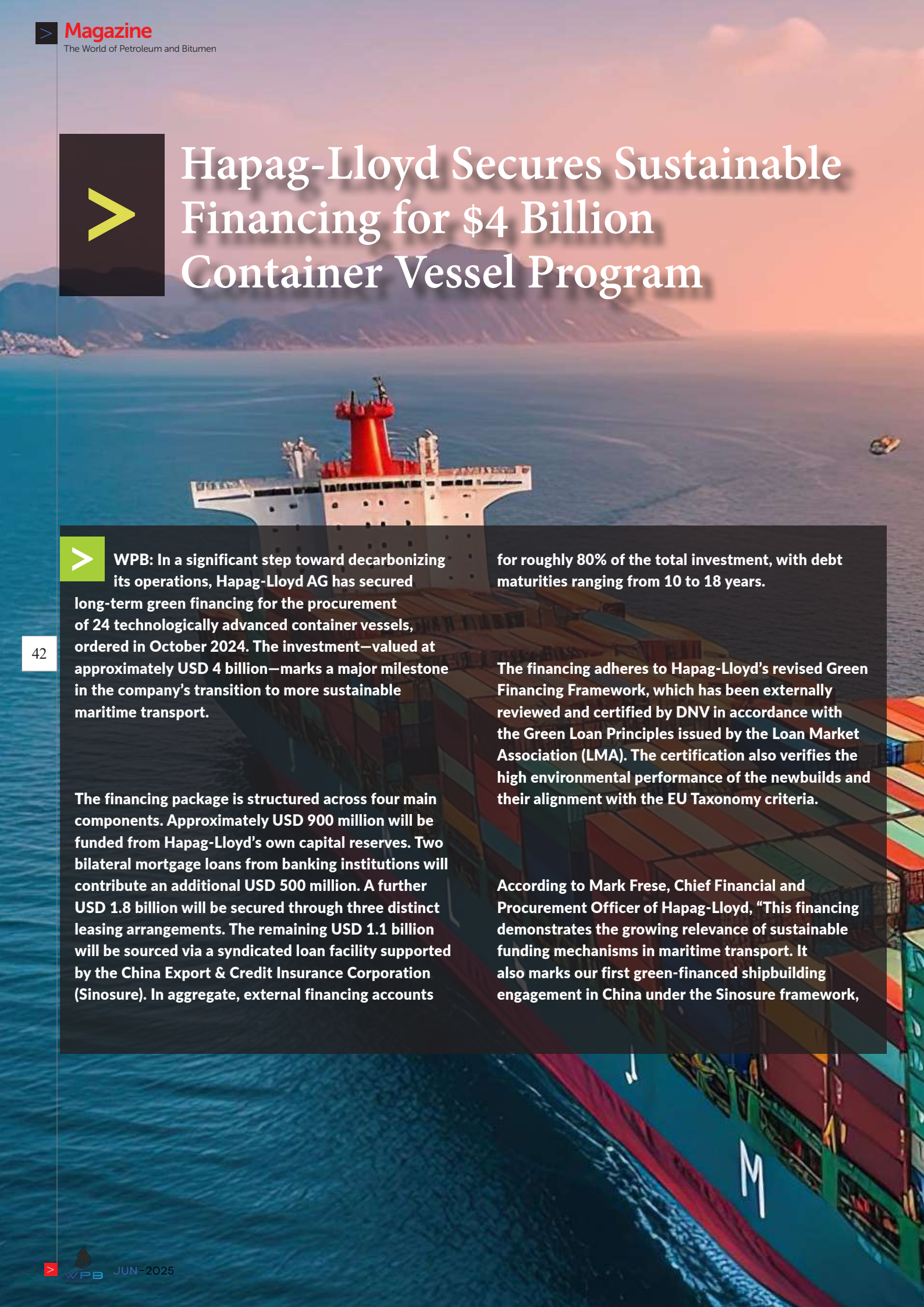
Hapag-Lloyd Secures Sustainable Financing for $4 Billion Container Vessel Program



WPB: In a significant step toward decarbonizing its operations, Hapag-Lloyd AG has secured long-term green financing for the procurement of 24 technologically advanced container vessels, ordered in October 2024. The investment—valued at approximately USD 4 billion—marks a major milestone in the company's transition to more sustainable maritime transport.

The financing package is structured across four main components. Approximately USD 900 million will be funded from Hapag-Lloyd's own capital reserves. Two bilateral mortgage loans from banking institutions will contribute an additional USD 500 million. A further USD 1.8 billion will be secured through three distinct leasing arrangements. The remaining USD 1.1 billion will be sourced via a syndicated loan facility supported by the China Export & Credit Insurance Corporation (Sinosure). In aggregate, external financing accounts for roughly 80% of the total investment, with debt maturities ranging from 10 to 18 years.

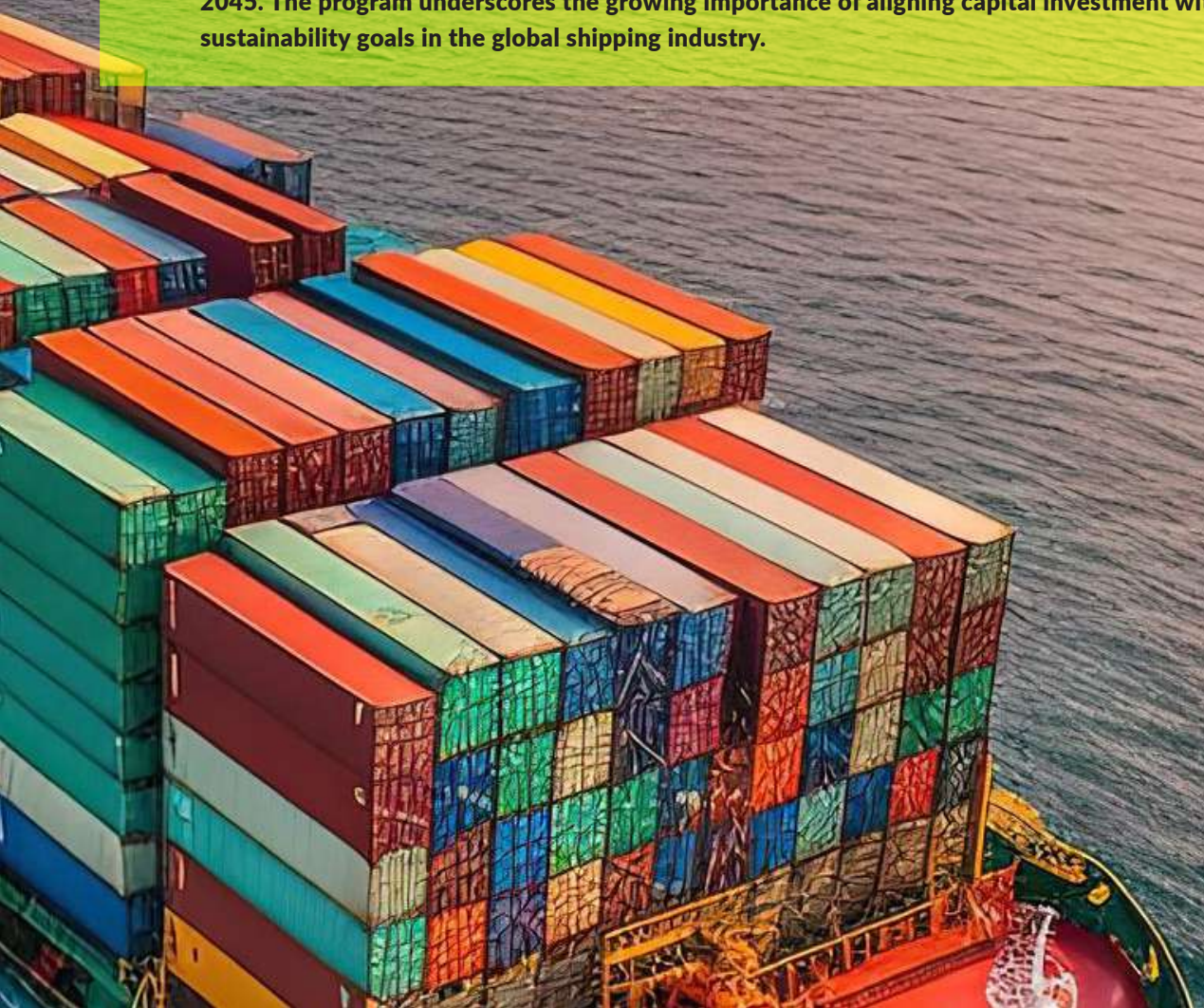
The financing adheres to Hapag-Lloyd's revised Green Financing Framework, which has been externally reviewed and certified by DNV in accordance with the Green Loan Principles issued by the Loan Market Association (LMA). The certification also verifies the high environmental performance of the newbuilds and their alignment with the EU Taxonomy criteria.

According to Mark Frese, Chief Financial and Procurement Officer of Hapag-Lloyd, "This financing demonstrates the growing relevance of sustainable funding mechanisms in maritime transport. It also marks our first green-financed shipbuilding engagement in China under the Sinosure framework,

reflecting our broader strategic alignment with international partners."

The vessels, scheduled for delivery between 2027 and 2029, will be constructed in Chinese shipyards and equipped with high-pressure dual-fuel engines designed for low-emission liquefied gas propulsion. The engines will also be capable of operating on biomethane, which offers the potential for up to 95% reduction in CO_2-equivalent emissions compared to conventional fuels.

Moreover, the ships are engineered to be ammonia-ready, positioning them for future compliance with emerging fuel technologies.This initiative forms part of Hapag-Lloyd's broader climate commitment, which includes a 30–35% reduction in absolute greenhouse gas emissions by 2030 (relative to 2022 levels) and a target of net-zero emissions fleet-wide by 2045. The program underscores the growing importance of aligning capital investment with sustainability goals in the global shipping industry.



Asphalt

Bill Gates' Carbon-Absorbing Asphalt Begins Real-World Use

Roughly a year ago, Bill Gates visited the Seattle headquarters of Modern Hydrogen — an environmental tech venture he's backed — and lent a hand in a demonstration, filling a test pothole with a new kind of asphalt. Despite some awkwardness handling construction tools, the billionaire philanthropist helped showcase a promising innovation: a road surface material infused with captured carbon.

This material, known as Modern Carbon, incorporates solid carbon derived from natural gas. The carbon is extracted and locked into the asphalt, forming a carbon-sequestering mixture that functions like traditional pavement. According to Michael Baba, the company's senior product development manager, the test patch remains intact after a year of daily traffic. "It blends in seamlessly with the road — just what you want from a well-performing asphalt," he noted.

Founded in 2015 with Gates' support, Modern Hydrogen developed a unique process using a methane pyrolysis reactor. This device separates carbon from methane — sourced either from fossil fuels or renewable materials like manure — producing clean hydrogen gas that emits only water vapor. A byproduct of the process, the extracted solid carbon, can be directly used in asphalt, replacing petroleum-based bitumen. This shift results in lower greenhouse gas emissions, permanent carbon storage, and up to 20% cost reduction.

These developments reflect the infrastructure sector's growing commitment to sustainability and innovative materials.

Given that asphalt covers about 90% of the world's roads, and that bitumen is a major contributor to the sector's carbon footprint, the implications are significant. Modern Hydrogen states that using Modern Carbon can cut material emissions by 20% and reduce overall lifecycle emissions of pavement by 11%.

The performance of this new asphalt — including its durability against rutting and cracking — has earned recognition from the American Association of State Highway and Transportation Officials and meets ASTM International standards.

Since Gates' hands-on demo in early 2024, the material has transitioned from prototype to practice. In November, Bexar

County, Texas, in coordination with Clark Construction, applied 100 tons of the product during road maintenance in San Antonio.

Aaron Martinez, a superintendent at Bexar County Public Works, expressed optimism: "We're always exploring better materials. Carbon-sequestered asphalt is definitely part of our future."

Smaller community-based applications have also taken place. In Long Beach, California, the Family of Faith Christian Center repaired its parking lot using around 100 tons of the material. Likewise, in Snohomish, Washington, a one-mile residential road was resurfaced using Modern Carbon, showing its effectiveness for neighborhood-scale projects.

Modern Carbon has since been utilized in several U.S. states and Canadian provinces, including Alberta. In Long Island, Modern Hydrogen worked with National Grid to integrate the product during gas line replacements, reducing emissions in tandem with infrastructure upgrades.

While Modern Carbon garners attention, broader industry trends in reducing asphalt's environmental impact continue. Notably, the use of recycled asphalt in new road construction rose from 15.6% in 2009 to 22.2% in 2022, according to the National Asphalt Pavement Association.

These developments reflect the infrastructure sector's growing commitment to sustainability and innovative materials.

Major Buyer

Venezuela Urgently Seeks Increased Oil Sales to China Amid Mounting Pressure

WPB: Venezuela's critical oil sector is deteriorating, and the root cause extends far beyond internal issues like broken-down facilities or ongoing administrative failures. The country finds itself trapped in a complex mix of international pressure, economic sanctions, and political urgency—all converging to isolate Caracas as the U.S. tightens restrictions.

In a recent diplomatic mission to Beijing, Vice President Delcy Rodríguez made a pressing appeal: Venezuela needs China to boost its oil purchases immediately. With Washington pushing foreign companies such as Chevron out of Venezuela and imposing heavy penalties—including 25% tariffs—on anyone engaging in its oil trade, the government is making a

last-ditch effort to hold on to its final major buyer.

However, China's response has been less than enthusiastic. Reports suggest that Chinese authorities are demanding deeper price cuts and are pushing to revise existing agreements. Being the only significant customer remaining gives them considerable leverage to negotiate tougher terms.

Meanwhile, Venezuela's oil export levels are in freefall. Shipments have already plunged by nearly a fifth as PDVSA halted Chevron's scheduled loadings prematurely. Desperate tactics are becoming more visible, with disguised oil tankers—dubbed "zombie ships"—attempting to bypass international tracking systems. Such maneuvers underscore the gravity of the situation.

Although China remains Venezuela's biggest creditor and continues to receive oil as loan repayments, even that flow is waning. Output at the once-prominent Sinovensa joint venture between China's CNPC and PDVSA has tumbled to 103,000 barrels per day, a stark drop from 160,000 in 2015.

Adding to the pressure, the U.S. administration is now warning that countries persisting in Venezuelan oil trade could face additional penalties. This raises the stakes for China, which might become the next target of secondary sanctions. For Venezuela, losing its last dependable oil client could deal a devastating blow. The nation's foreign reserves are vanishing, its currency is nosediving once again, and inflation continues to rise sharply.

Although Rodríguez described her meetings in China as "confidential" and expressed satisfaction, observers view the trip as a desperate gamble to rescue a collapsing lifeline.

POSITIONING THE TRANSPORTATION INDUSTRY IN THE SUPPLY CHAIN OF PETROLEUM AND PETROCHEMICAL PRODUCTS

(Part Two: Topics Related to the Petroleum and Petrochemical Product Supply Chain)

By Amir Rezaei from Sokan Arya Darya Company

In today's globally competitive market, supply chain management holds significant importance. The strategy of supply chain management serves as a framework for optimizing the performance of organizations and companies, and it is considered one of the key managerial indicators today. At its core, supply chain management refers to managing the process of producing and delivering goods and services, including planning, execution, quality control, and the delivery of products and services to meet consumer needs in the most efficient and optimal manner.

Activities such as supplying raw materials, transporting them, warehousing, using raw materials for producing and distributing products, and delivering goods to the end consumer are all components of the supply chain. Individuals such as raw material suppliers, manufacturers, investors, wholesalers, retailers, and distributors all play roles within the supply chain and are considered part of it.

However, supply chain management consists of five main components, each playing a crucial role in the process. These five main components are as follows:

- Planning: This is the most fundamental and essential stage of supply chain management. In this phase, business owners should focus on developing a strategic plan aimed at increasing profitability. Supply chain management mainly focuses on planning and developing a set of criteria to efficiently meet customer needs and demands.

- Sourcing: After detailed planning, the next step is to develop and find appropriate sources. This means identifying suitable suppliers for obtaining raw materials and essential inputs for your products.

- Production: The production phase involves manufacturing and supplying the products needed by customers. At this stage, products are designed, produced, tested, packaged, and prepared for delivery to customers.

- Delivery: The delivery or logistics segment is responsible for coordinating and managing all aspects of product delivery to customers. Final products are delivered from the supplier to the end consumer. This stage is commonly referred to as logistics, and companies collaborate on order receipt and delivery, warehousing, and selecting appropriate transportation methods. This segment connects supply chain management with logistics.

- Returning: This is the final stage of supply chain management, in which defective or damaged products are returned by customers to the supplying company.
In this phase, the company must address customer complaints and requests and resend the correct or satisfactory product.

Refineries, petrochemical plants, storage facilities, and demand centers are the key components of the petroleum product distribution network. The growing demand in recent years, along with differences in the infrastructure of various modes of transportation between these components, necessitates the optimal distribution of petroleum products.

This excessive demand itself becomes a factor that threatens the sustainability of the supply chain, particularly within the distribution chain — including distribution channels, distribution sites, and transportation systems — leading to various operational challenges.

Bahrain's Bitumen Exports Set to Fall as Refineries Undergo Upgrades

目前，锡特拉的海运沥青报价保持稳定，离岸价为每吨370美元，已连续数周未变。

由于地区竞争对手提供了更具竞争力的价格，今年以来外界对巴林沥青的出口兴趣有所减弱

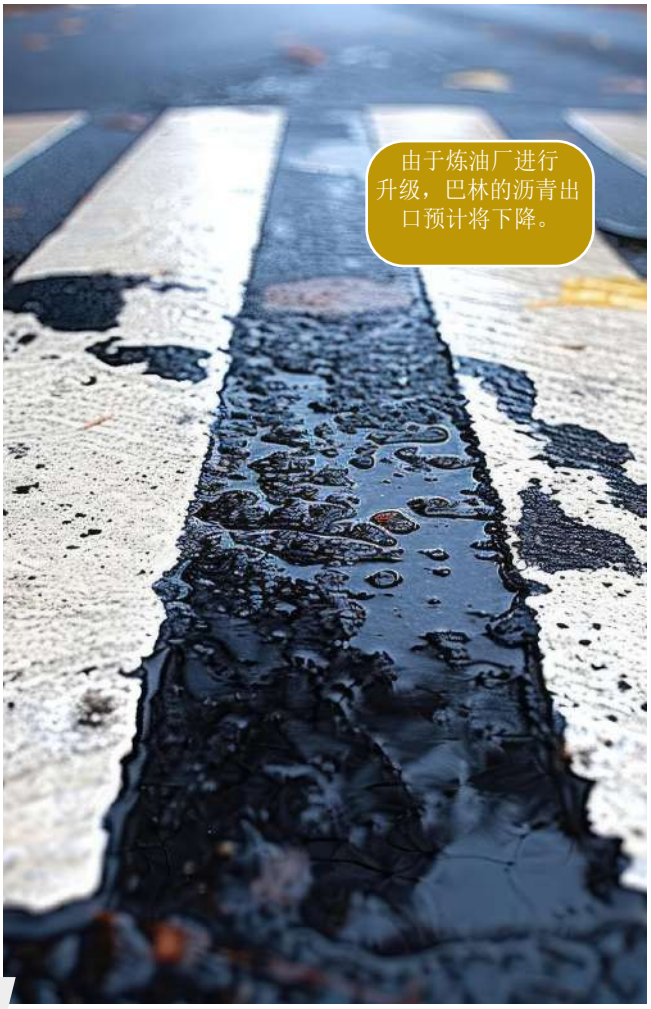
According to WPB, bitumen availability for export from Bahrain is set to contract in the near future as the state-owned Bapco refinery in Sitra undergoes scheduled maintenance and continues its transition under a major modernisation initiative. Sources among global bitumen traders and importers confirm that output from the 267,000 barrels-per-day facility will be affected as part of operational adjustments linked to the plant's ongoing upgrades.

The upcoming shutdown of the vacuum distillation unit (VDU), a core component in bitumen production, is anticipated to significantly limit the refinery's capacity to supply export volumes. Market players familiar with the refinery's operations noted that the maintenance period is expected to span several weeks. During this interval, waterborne bitumen shipments will reportedly be suspended, with existing stocks prioritized for internal demand. No further technical details regarding the maintenance duration or extent have been disclosed.

Currently, seaborne bitumen offers from Sitra remain stable at $370 per tonne on a free-on-board basis—unchanged for several weeks. However, shipping data from analytics provider Kpler reveal recent and upcoming movements of the Sidra Al Wakra vessel, which loaded a 3,100-tonne cargo from Sitra for delivery to Qatar. Another similar cargo is scheduled to be loaded shortly, though it remains uncertain whether this will be the final shipment before operations pause.

Export interest in Bahraini bitumen has diminished throughout the year due to more competitive pricing from regional rivals. Iranian suppliers, in particular, have drawn attention by offering considerable

Bahrain's Bitumen



由于炼油厂进行升级，巴林的沥青出口预计将下降。

> Currently, seaborne bitumen offers from Sitra remain stable at $370 per tonne on a free-on-board basis—unchanged for several weeks.

discounts. On average, Iran's bulk bitumen prices have trailed Bahrain's fob rates by $109.90 per tonne throughout the year, with the gap widening to as much as $201 per tonne during previous market cycles. As of a recent assessment, Iranian cargoes were priced at $342.50 per tonne—$27.50 below Bahrain's listed rate. Current demand for Bahraini bitumen is primarily limited to select markets such as Qatar, the UAE, and South Africa's Durban port, where buyers have specific grade requirements not met by alternative suppliers.

Simultaneously, the Sitra refinery continues to progress through the $7 billion Bapco Modernisation Project (BMP). This long-term upgrade is designed to boost overall processing capacity to 380,000 barrels per day. Although the facility's enhancement is expected to

production of higher-value middle distillates, it also implies a reduced share of heavier outputs, including bitumen, especially with the activation of new secondary processing units. Full details on the status and output configuration of these units remain unavailable.

With export constraints looming and structural shifts in product output underway, stakeholders across the region are closely monitoring the evolution of Bahrain's position in the international bitumen market.

巴林沥青

ENHANCING BITUMEN SUSTAINABILITY THROUGH NANOTECHNOLOGY: A COMPREHENSIVE REVIEW

Abstract

The increasing global emphasis on sustainable infrastructure has intensified the demand for environmentally resilient materials in road construction. Bitumen, a crucial binder in asphalt mixtures, has faced mounting challenges related to performance, durability, and environmental impact. Nanotechnology—an emerging field that manipulates matter at the molecular scale—offers promising solutions to these challenges. This review comprehensively explores the integration of nanotechnology into bituminous materials, highlighting advancements in mechanical performance, aging resistance, moisture susceptibility, and emission reduction. Additionally, it discusses current research trends, practical applications, and future prospects of nano-modified bitumen in fostering long-term sustainability in the pavement industry.

1. Introduction

In the wake of global environmental concerns and the pursuit of sustainable development goals (SDGs), the transportation and construction sectors have been under increasing pressure to adopt greener technologies. Bitumen, traditionally used as a binder in asphalt pavements, contributes significantly to greenhouse gas emissions and relies heavily on non-renewable resources. Moreover, conventional bituminous pavements often suffer from premature degradation due to traffic loads, temperature fluctuations, and oxidative aging.

Recent advances in nanotechnology present a transformative opportunity to overcome these limitations. By incorporating nanomaterials such as nano-clay, nano-silica, carbon nanotubes, graphene oxide, and nano-TiO into bitumen, researchers have observed marked improvements in various performance attributes of asphalt mixtures. These enhancements include increased stiffness, better temperature susceptibility control, and enhanced resistance to fatigue, rutting, and moisture damage.

This article delves into the pivotal role of nanotechnology in revolutionizing bitumen performance and sustainability. It aims to provide an in-depth understanding of the mechanisms by which nanomaterials influence bituminous properties and to assess their viability for widespread implementation in sustainable infrastructure.

2. Types of Nanomaterials Used in Bitumen Modification

Nanomaterials are categorized based on their chemical structure, origin, and dimensional characteristics. In the context of bitumen modification, they are selected for their specific physical, chemical, and mechanical properties that influence the binder's performance. Below is an overview of the most commonly used nanomaterials in asphalt technology:

2.1 Nano-clay

Nano-clays, particularly montmorillonite, have layered silicate structures that offer a large surface area and high aspect ratio. When dispersed uniformly in bitumen, nano-clays enhance stiffness, thermal stability, and resistance to aging. Their lamellar morphology can create a tortuous path for oxygen and water molecules, thus slowing down oxidative degradation and moisture penetration.

2.2 Nano-silica

Nano-silica, typically synthesized through sol-gel processes or extracted from industrial byproducts, is known for its high surface area and pozzolanic activity. It improves the viscoelastic properties of bitumen, reduces penetration depth, and enhances thermal resistance. Moreover, nano-silica can fill micro-voids in the bitumen matrix, reducing permeability and improving fatigue life.

2.3 Carbon Nanotubes (CNTs)

CNTs, including single-walled and multi-walled variants, possess exceptional tensile strength, electrical conductivity, and thermal stability. When incorporated into bitumen, they significantly enhance mechanical strength, elasticity, and rutting resistance. However, dispersion challenges and high costs limit their widespread use, although surface functionalization techniques have shown promise in addressing these issues.

2.4 Graphene and Graphene Oxide

Graphene derivatives are among the most promising nanomaterials for bitumen modification due to their unique two-dimensional structure and multifunctional properties. Graphene oxide (GO), in particular, improves stiffness, reduces temperature susceptibility, and provides excellent anti-aging performance due to its barrier properties and interaction with bituminous components.

2.5 Nano-Titanium Dioxide (TiO)

Nano-TiO is widely used for its photocatalytic properties, which contribute to self-cleaning and NOx degradation in asphalt pavements. In addition to environmental benefits, nano-TiO enhances UV resistance, surface reflectivity, and aging resistance of bitumen. Its integration is particularly relevant in urban areas seeking sustainable and smart infrastructure solutions.

2.6 Other Nanomaterials

Additional nanomaterials such as nano-zinc oxide (ZnO), nano-alumina (AlO), and nano-calcium carbonate (CaCO) have been studied for their roles in improving rheological properties, enhancing stiffness, and reducing oxidative aging. Their selection depends on project-specific performance targets, economic considerations, and environmental compatibility.

3. Effects of Nanomaterials on Bitumen Properties

The incorporation of nanomaterials into bitumen leads to significant improvements in its physical, chemical, and rheological properties. These enhancements directly translate into better performance, durability, and sustainability of asphalt pavements under diverse environmental and traffic conditions.

3.1 Rheological Improvements

Nanomaterials such as nano-clay and nano-silica improve the complex modulus and reduce phase angle in bitumen, indicating a stronger elastic response and enhanced resistance to deformation. These changes are particularly beneficial in resisting rutting at high temperatures and cracking at low temperatures. Dynamic Shear Rheometer (DSR) tests have shown that nanomodified binders exhibit superior performance grading compared to conventional ones.

3.2 Enhanced Thermal Stability

Nano-additives help maintain binder integrity across a wider temperature range. For instance, nano-silica and nano-TiO increase the softening point and reduce temperature susceptibility, which ensures a more consistent performance in both hot and cold climates. This thermal resilience is critical for pavements exposed to extreme seasonal variations.

3.3 Improved Aging Resistance

Oxidative aging is a major factor in bitumen deterioration. Nanomaterials such as graphene oxide and nano-clay act as effective anti-aging agents by forming physical and chemical barriers that limit the penetration of oxygen and UV radiation. Long-term aging simulations (e.g., Rolling Thin Film Oven Test and Pressure Aging Vessel) reveal that nanomodified bitumen retains higher ductility and lower stiffness compared to unmodified binders.

3.4 Moisture Damage Resistance

Moisture sensitivity in asphalt mixtures often leads to stripping and loss of cohesion. Nanoparticles improve moisture resistance by enhancing the adhesion between bitumen and aggregate. The hydrophobic nature of certain nanomaterials (e.g., modified nano-silica) reduces water absorption, while their small size helps fill microvoids and create a denser matrix.

3.5 Improved Fatigue Life

Fatigue cracking occurs due to repeated loading over time. Nanomaterials increase the binder's elasticity and flexibility, thereby reducing the likelihood of microcrack formation. Laboratory fatigue tests (e.g., Time Sweep, Four-Point Bending) show that nanomodified binders extend the service life of pavements by delaying crack propagation.

3.6 Enhanced Storage Stability and Workability

Some nanomaterials contribute to better compatibility between bitumen and other additives (e.g., polymers or recycled materials). This leads to improved storage stability, reduced phase separation, and better workability during mixing and compaction. For instance, nano-TiO and CNTs enhance the dispersion of other modifiers within the binder.

4. Nanotechnology and Bitumen Sustainability

Nanotechnology not only improves the technical performance of bitumen but also plays a pivotal role in enhancing its environmental and economic sustainability. This alignment with sustainable development goals (SDGs) is particularly critical as the construction industry seeks greener and more durable infrastructure solutions.

4.1 Energy and Resource Efficiency

Nanomaterials can reduce the energy consumption associated with bitumen production and application. For example, warm mix asphalt technologies, which operate at lower temperatures, benefit from nanomaterial-enhanced binders that maintain performance despite reduced heat. This results in lower fuel use, decreased emissions, and improved worker safety.

Furthermore, the improved durability of nanomodified bitumen reduces the frequency of maintenance and rehabilitation, indirectly minimizing the consumption of natural resources and energy over the pavement's lifecycle.

4.2 Reduction of Environmental Impact

The environmental footprint of asphalt pavements can be significantly lowered by using nanotechnology. Nanomaterials help reduce emissions during the production and laying of asphalt. Moreover, their ability to enhance the performance of recycled asphalt pavement (RAP) increases the use of reclaimed materials, thus diverting waste from landfills and reducing the demand for virgin aggregates and binders.

Some nanoparticles, such as nano-TiO, also exhibit photocatalytic properties, enabling the breakdown of pollutants (e.g., NO and VOCs) from vehicle exhaust when used in surface layers. This adds an air-purifying function to pavements, contributing to better urban air quality.

4.3 Life Cycle Extension

Nanomodified bitumen typically exhibits improved resistance to rutting, fatigue, thermal cracking, and oxidation. These characteristics significantly extend the service life of pavements, reducing the need for frequent repairs or overlays. A longer pavement lifespan equates to fewer disruptions, lower lifecycle costs, and reduced environmental impact over time.

4.4 Compatibility with Bio-based and Recycled Materials

Nanotechnology can also facilitate the integration of eco-friendly additives like bio-asphalts and industrial by-products. The addition of nanoparticles improves the compatibility between bitumen and bio-based materials, ensuring performance is not compromised. This synergy supports circular economy principles and the development of low-carbon road construction techniques.

4.5 Economic Sustainability

Although the initial cost of nanomaterials may be higher, the long-term savings achieved through extended pavement life, lower maintenance needs, reduced energy consumption, and higher resource efficiency make nanotechnology a cost-effective investment. Life Cycle Cost Analysis (LCCA) models demonstrate favorable economic outcomes when nano-enhanced binders are employed in road infrastructure projects.

5. Case Studies and Practical Applications

The integration of nanotechnology in bitumen modification is not merely theoretical—it has been successfully implemented in various real-world applications across different regions. These case studies highlight the practical benefits, challenges, and outcomes of using nanomaterials in asphalt technologies.

5.1 Nano-clay in Indian Highways

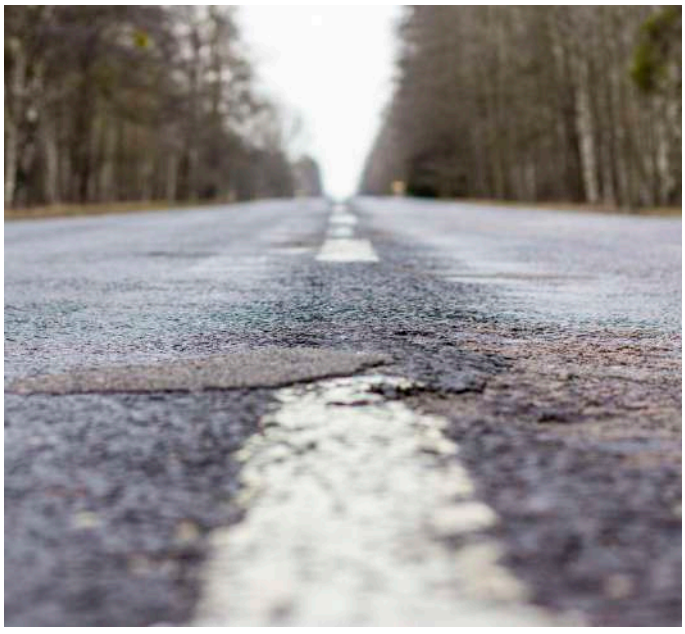
India's National Highway Authority conducted field trials using nano-clay-modified bitumen on stretches of high-traffic roads. The modified binder demonstrated enhanced rutting resistance and better thermal stability under high ambient temperatures. Over a two-year monitoring period, the pavement showed fewer surface distresses compared to conventional asphalt, validating the efficacy of nano-clay in hot and humid climates.

5.2 Nanosilica in European Cold Regions

In Scandinavian countries, where freeze–thaw cycles are a significant concern, nanosilica has been introduced to improve resistance against thermal cracking. The fine particle size and high surface area of nanosilica improve the elasticity and reduce stiffness of the bitumen, maintaining flexibility in sub-zero conditions. These modifications have resulted in fewer maintenance cycles and improved ride quality.

5.3 Carbon Nanotubes in the United States

Pilot projects in the U.S. have utilized carbon nanotube (CNT)-enhanced bitumen in heavy-load transportation corridors. These routes experienced substantial reductions in fatigue cracking and deformation due to the superior tensile strength and electrical conductivity of CNTs. Although cost remains a concern, the high-performance metrics observed have justified their use in critical infrastructure segments.



5.4 Photocatalytic Nanoparticles in Urban Settings

Several urban municipalities, including in Japan and the Netherlands, have deployed nano-TiO-based asphalt in pedestrian zones and parking lots. These materials provide self-cleaning properties and actively degrade air pollutants through photocatalysis. Monitoring data has shown measurable reductions in NO concentrations around these surfaces, supporting their role in enhancing urban air quality.

5.5 Recycled Asphalt and Nanotechnology in China

In China, efforts to improve the performance of high RAP-content mixtures have involved the use of nanosilica and nano-ZnO. These nanoparticles improve the cohesion between aged and virgin binders and reduce oxidative hardening. This has enabled the successful construction of eco-efficient pavements with up to 50% RAP content, demonstrating both environmental and cost benefits.

6. Challenges, Limitations, and Future Prospects

While nanotechnology presents significant potential for transforming bitumen performance and sustainability, its widespread adoption faces several technical, economic, and regulatory challenges that must be addressed.

6.1 Economic Barriers

One of the primary concerns is the cost of nanomaterials, particularly carbon-based nanoparticles such as CNTs and graphene. Although they offer exceptional mechanical properties, their high production and processing costs limit their use to specialized applications. For more cost-effective adoption, scalable and affordable synthesis methods are needed.

6.2 Health and Safety Considerations

The toxicological profile of certain nanomaterials is not fully understood. Prolonged exposure to airborne nanoparticles during mixing or construction processes may pose respiratory hazards to workers. Rigorous health risk assessments and proper handling protocols must be developed and enforced.

Future Directions

6.3 Dispersion and Compatibility

Achieving uniform dispersion of nanoparticles in bitumen is a persistent technical challenge. Poor dispersion can lead to agglomeration, which negatively affects the material's performance. Surface treatment of nanoparticles or the use of surfactants and compatibilizers can mitigate this issue, but adds complexity to the process.

6.4 Lack of Standardization

Currently, there is a lack of standardized testing procedures and specifications for nano-modified bitumen. This makes it difficult to compare results across studies or implement quality control measures in production. Industry-wide collaboration is needed to establish consensus-based guidelines and benchmarks.

6.5 Environmental Impact and Life Cycle Assessment

Although nanomaterials can enhance sustainability by extending pavement life and enabling higher RAP use, their full life cycle environmental impacts are not yet completely known. More research is required to evaluate potential nanoparticle leaching, persistence in ecosystems, and long-term ecological effects.

6.6 Future Directions

To fully harness the promise of nanotechnology, the following developments are essential:

- Green nanotechnology: Research into bio-based and biodegradable nanoparticles that can replace conventional options while minimizing environmental risks.
- Smart pavements: Integration of functional nanomaterials (e.g., piezoelectric, self-sensing, or self-healing) to enable intelligent road

HEALTH AND SAFETY CONSIDERATIONS

ECONOMIC BARRIERS

FUTURE DIRECTIONS

durability, and sustainability of pavement materials. The integration of nanomaterials—such as nano-silica, nanoclays, carbon nanotubes, and graphene—into bitumen can significantly improve mechanical, thermal, and aging resistance properties, while simultaneously contributing to environmental sustainability goals through reduced energy consumption and enhanced recyclability.

Despite these advantages, several technical and non-technical barriers must be overcome before widespread implementation becomes feasible. These include high production costs, safety concerns, dispersion difficulties, and a lack of regulatory standards. Nonetheless, the ongoing advancement of material science, coupled with growing support from governmental and industrial stakeholders, signals a promising future.

For countries seeking to modernize their infrastructure and reduce the carbon footprint of road construction, nano-engineered bitumen offers a compelling solution. Continued interdisciplinary research and collaboration between academia, industry, and policymakers will be essential to translate laboratory innovations into scalable, real-world applications.

In conclusion, nanotechnology does not merely represent a marginal improvement to traditional bitumen—it has the potential to redefine how we design and build the roads of tomorrow.

WPB

CONCLUSION

systems.

- AI-assisted material design: Use of artificial intelligence and machine learning to optimize formulations and predict long-term performance.
- Policy support: Government incentives and R&D funding to support the commercialization of nano-enhanced bitumen products.

7. Conclusion

Nanotechnology is emerging as a transformative force in the bitumen and asphalt industry, offering unprecedented opportunities to enhance the performance,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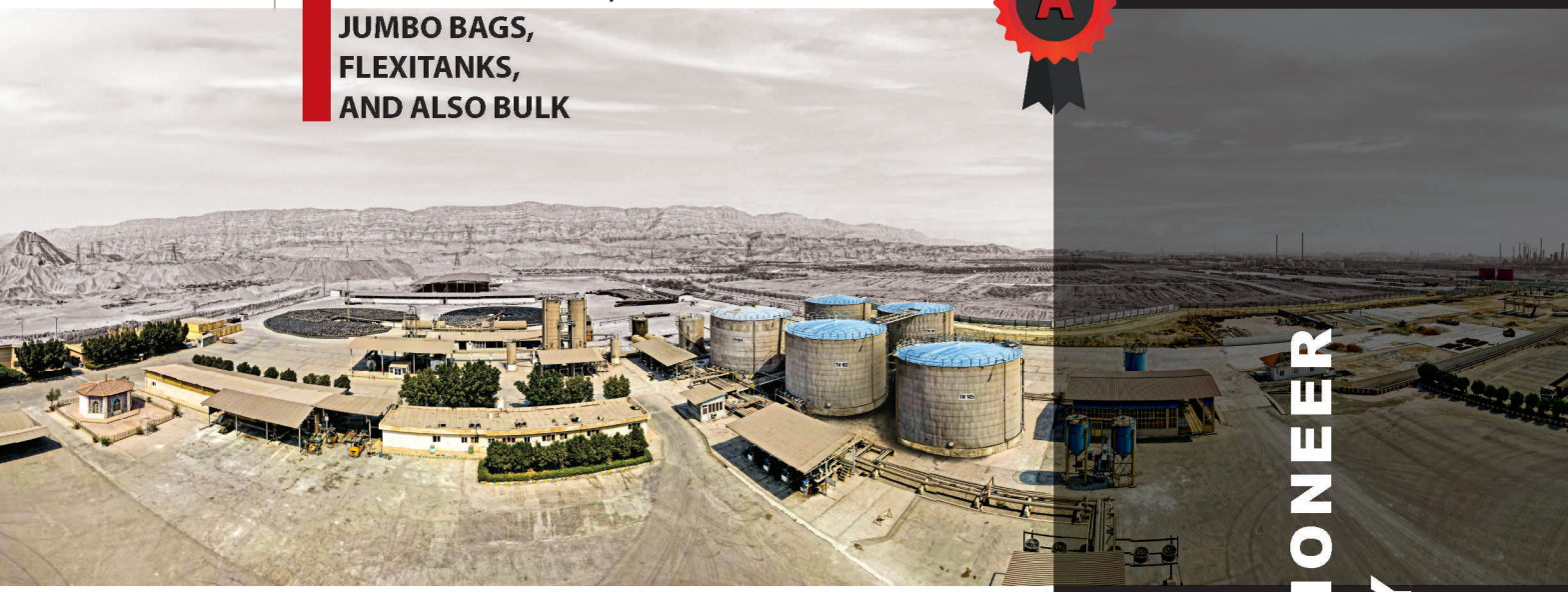

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