LAPORAN
ANUGERAH INOVASI NEGERI SELANGOR TAHUN 2024

Tajuk Inovasi:

FILPRO GEOPOLYMER

– Emergency Road Repair Material –

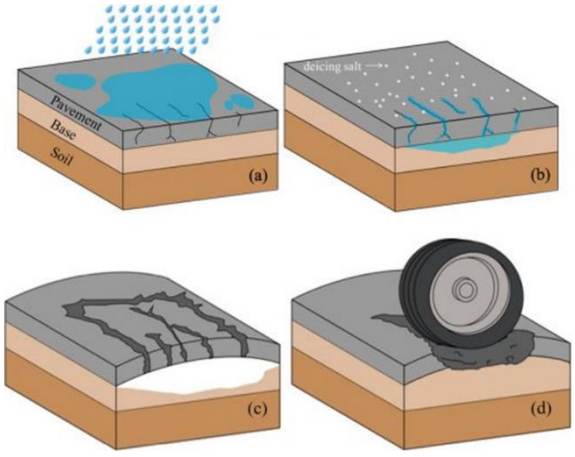
Nama Jabatan: Pengajian Kejuruteraan Awam, Kolej Pengajian Kejuruteraan, Universiti Teknologi MARA Shah Alam.

Introduction:

Introducing **FILPRO**, geopolymer based concrete repairing materials with DIY concept. This product using advanced geopolymer technology with greener materials to overcome various pavement damage and problems.

Typical pavement problems include:

- Potholes
- Cracking
- Depressions
- Rutting
- Shoving
- Upheavals
- Raveiling
- Crazing
- Softness
- Poor abrasion resistance
- Unacceptable surface finish



In all cases the failures can be traced to one or more of the following:

- Inadequate specifications
- Poor materials selection
- Incorrect mix proportions
- Poor site practice and bad habits

Summary of the product:

Potholes are problematic damage on road surfaces. It caused many problems for road users all over the world. Potholes cause a lot of accidents, even some of which end in death. To resolve the problems, recovery and repair work of potholes needs to be solved as soon as possible. Patching potholes with cold mix asphalt is the most popular repair technique applied, but it is considered an impermanent solution. Even the cold-mixed asphalt fixes pothole problems speedily, but it is not durable and tends to lose its performance after a short period. It worsened when the road surface was directly exposed to extreme environmental conditions. Due to all the problematic issues that occurred, FILPRO was introduced. FILPRO was designed to produce superb quality materials with excessive qualities and satisfied the needs of the standard requirement for pothole repairs. Through the green geopolymerization concept, FILPRO successfully performed in resolving the potholes issues by offering DIY values, easy to handle, high workability, fast setting, non-toxic, superbly physical, mechanical, and high durability properties. With attention to the economic value of the product, FILPRO offers a better solution to improve the overall construction cost and time. “FILPRO is the answer for pothole problems”.

Date of product innovation: 01 NOVEMBER 2022

AKTA HAK CIPTA 1987

PERATURAN-PERATURAN HAK CIPTA (PEMBERITAHUAN SUKARELA) 2012

SIJIL PEMBERITAHUAN HAK CIPTA
[Subperaturan 8(2)]

No. Pemberitahuan	:	**CRLY2022W04898**
Tajuk Karya	:	**FILRO: EMERGENCY ROAD REPAIR MATERIAL**
Jenis Karya	:	**SASTERA**
Tarikh Permohonan	:	**01 NOVEMBER 2022**

Saya dengan ini mengesahkan di bawah Akta Hak Cipta 1987 [Akta 332] dan Peraturan-Peraturan Hak Cipta (Pemberitahuan Sukarela) 2012 bahawa karya hak cipta dengan No. Pemberitahuan seperti di atas bagi pemohon **UNIVERSITI TEKNOLOGI MARA** sebagai **PEMUNYA** dan **WARID WAZIEN BIN AHMAD ZAILANI (92122025215), MOHD FADZIL BIN ARSHAD (741203085947), NAZIRAH BINTI MOHD APANDI (931102015736), ZULHAZIQ KHAN BIN ZULJAR (970613565141)** sebagai **PENCIPTA** telah didaftarkan ke dalam Daftar Hak Cipta menurut seksyen 26B Akta Hak Cipta 1987 [Akta 332].

ABDUL HARIS BIN HAJI LAKAR
PENGAWAL HAK CIPTA
MALAYSIA

(Agensi di bawah Kementerian Perdagangan Dalam Negeri dan Kos Sara Hidup)

Objective of this product:

Potholes is one of the critical problems faced by road users worldwide. This problem not only causes discomfort to road users, but also causes road accidents. Statistics show that more than 15% of road accidents are caused by road surface problems such as potholes and broken roads (Paultan, 2021). In addition, 52,295 reports on potholes in Selangor were recorded on mobile navigation app Waze between January 2019 and September 2020 by road users (The Star, 2020). There are a couple of factors involved in road failures, such as road design, repair material, construction method, and environmental factors (Ratnasamy, 2018).

FILPRO was proposed as potholes road repair materials using a special formulation of nano geopolymer technology (FILGAP) combined with classified filled material (FILPOT) to produce high strength and durable properties. The nano geopolymerization of FILPRO creates a grout bonding characteristic in improving bonding at the interfacial zone between the old asphaltic materials with FILPRO materials while FILPOT contributes as durable filled material to the pothole. FILPRO was also designed to have a practical efficient fast setting. Test results indicated that the use of FILPRO gave sufficiently high compressive strength (more than 80 MPa) and bonding strength (more than 25 MPa) compared with the commercialized repair material (cold mix asphalt, SIKA, and etc.) suggesting that it could be used as an alternative and excellent product for repair works.

FILPRO has emerged as an environmentally sustainable repair products in construction industry. Fly ash that contains high silica (SiO_2) and alumina (Al_2O_3) is used as the main precursor in the production of FILPRO. In Malaysia, there are six coal-fired electric power stations that produce a significant volume of fly ash. A pozzolanic property from fly ash in FILPRO shows a good potential to be used as FILPRO's main precursor. The development of FILPRO could contribute to reduce CO_2 emissions with no economic sacrifices, while at the same time converting a potentially hazardous by-product into a valuable product.

Bitumen-based repair material has a slow setting which takes more than 24 hours to harden and is very sensitive to high alkalinity environments. Unlike FILPRO, it is a quick and fast setting repair material that is less than 10 minutes to harden and has no shrinkage problems. It has a highly dense surface with low water absorption (0.4 to 2.0%), and high fire resistance (100 – 1000oC), as to the latter they are more cost-effective (40-50 USD per m3) as compared to existing repair material (USD 50 - 70 per m3). With attention to the economic value of the product and high-performance repair material, FILPRO offers a better solution to improve the overall maintenance cost, time, and quality. FILPRO is the best solution to solve road potholes in Malaysia and all around the world.

Implementation Process of the Product

The process of developing and implementing operations and technical plans and strategies begins with a thorough assessment and analysis phase. This involves conducting a comprehensive review of current operations, workflows, and processes to understand the existing state and identify gaps between current performance and desired outcomes. Additionally, a risk assessment is performed to evaluate potential vulnerabilities. On the technical side, requirements are gathered from stakeholders and end-users, a feasibility study is conducted to analyze the viability of proposed solutions, and a technology audit is undertaken to review existing infrastructure and capabilities.

Following the assessment, the strategy development phase ensures alignment with the organization's mission, vision, and long-term goals. This involves engaging key stakeholders for input and consensus, defining clear, measurable objectives, and prioritizing initiatives based on their impact, feasibility, and resource availability. Incorporating innovative solutions and industry best practices is also crucial at this stage.

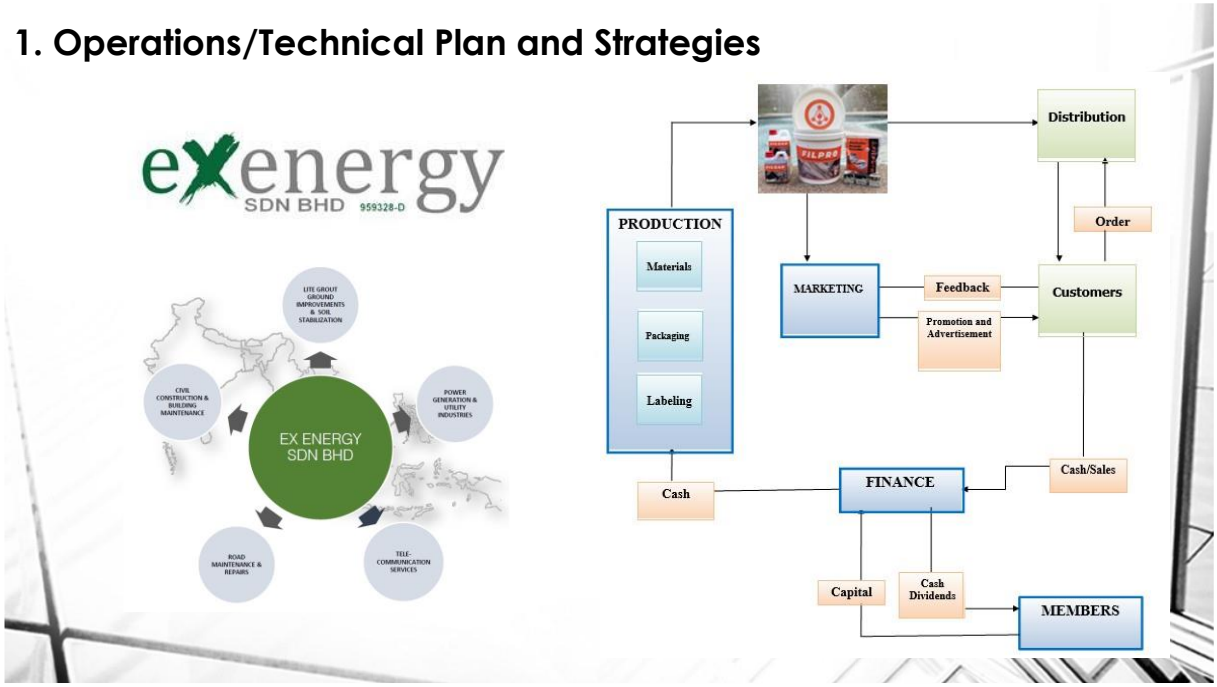
Resource allocation is the next critical step, involving a thorough evaluation of human resources to identify skills and competencies, and implementing training programs to address any gaps. Financial resources are planned through detailed budgeting and cost-benefit analysis, while technological resources are selected based on the technical requirements, and necessary infrastructure upgrades are planned.

Implementation planning is then carried out through comprehensive project management, developing a detailed project plan with defined scope, timeline, milestones, and deliverables. Task assignments are made based on expertise and availability, and risk mitigation strategies are developed alongside contingency plans. Change management plays a key role, with a communication plan to keep stakeholders informed and engaged, and assessing the organization’s readiness for change to address any resistance.

Execution of the plan involves launching the implementation phase with a kick-off meeting, regularly monitoring progress against the project plan, and employing quality control measures to ensure deliverables meet specified standards. Continuous improvement is pursued by collecting feedback and making iterative enhancements throughout the execution phase.

Finally, the evaluation and improvement phase involves monitoring key performance indicators (KPIs) to evaluate the effectiveness of the implemented strategies and conducting a post-implementation review to assess overall performance and identify lessons learned. Stakeholder feedback is gathered to understand satisfaction and areas for improvement, and performance data is analyzed to identify trends and insights. This feedback loop informs future strategic planning and continuous quality improvement initiatives, optimizing processes and ensuring sustained success.

1. Operations/Technical Plan and Strategies



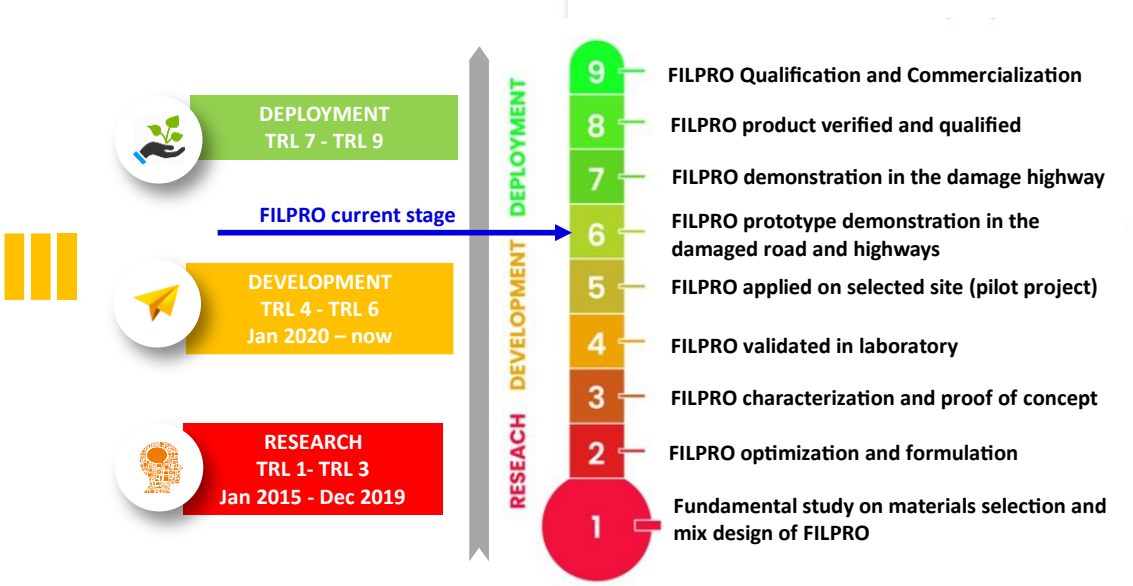
Process before produce this product:

Mix Proportion

The following cement mix ratios are intended for guidance only. The proportions shown are based on volume and using good quality materials such as sand. **FILPRO** cement can be used with all cement additives and admixtures when used in accordance with manufacturers' recommendations.

FILPRO recommends all users to carry out their own testing to ensure the right mix for their specification and requirements. We have put together some advice to help you get the right mix for whatever application you are using **FILPRO**

TECHNOLOGY READINESS LEVEL OF FILPRO



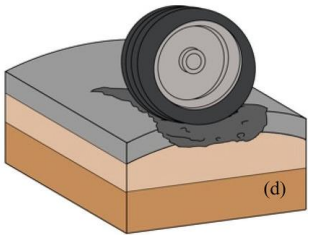
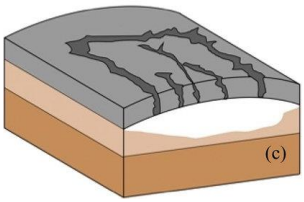
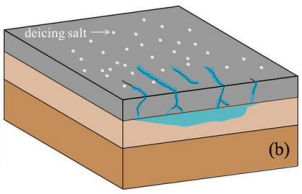
PHYSICAL & MECHANICAL PROPERTIES

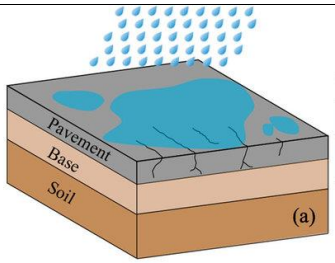
- **Compressive Strength***:* 15 – 100 MPa (depending on the fly ash used)
- **Flexural Strength***:* Approximately twice that of OPC
- **Chemical Resistance***:* Two to Five times greater resistance to sulfuric acid attack compared with OPC; virtually immune to sulfate attack
- **Porosity/Permeability***:* Lower than OPC Concrete utilized in typical structural applications
- **Strength Gain***:* Full strength is gained within 1 to 3 days; 80% of ultimate strength is gained within a 1-2 hours
- **Carbon Dioxide Emission***:* Less compared with OPC Concrete (i.e., 90% CO 2 emission reduction)
- **Resistance to the action of salt solutions** is better than that of the cement-based concrete
- The Green Concrete is **resistant to the corrosive environments**
- The strength values increase in the long run

NOVELTIES

- ✓ Replacement for OPC as a cementitious binder in the construction industry
- ✓ Alternative material to OPC
- ✓ Green concrete (without CO_2)- environmental friendly
- ✓ Utilization of material waste (fly ash)
- ✓ Towards waterproof repair material
- ✓ Stable at elevated temperatures

PROPERTIES	FILPRO	Commercialized Repair Material
Compressive Strength	15 – 100 MPa	10 – 60 MPa
Density	≈ 1800 - 2200 kg/m^3	≈ 2400 kg/m^3
Water Absorption	< 0.4 – 2.0 %	< 12.0 %
Fire Resistance	FIRE RESISTANT (100 – 1000 ºC)	≈ 2 Hour (500ºC)
Price	USD 40 -50 per m^3	USD50 – 70 per m^3

	Application	Recommended Mix Design
	• Patch	Solid : Liquid 2: 1 Solid : Sand : Aggregate 1 : 2 : 3
	• Grout	Solid : Liquid 2 : 1 Solid : Sand 1 : 2
	• Screed • Grout	Solid : Liquid 1 : 1 Solid : Sand 1 : 2
	• Render • Patch	Solid : Liquid 1 : 1

		Solid : Sand 1 : 1
The following cement mix ratios are intended for guidance only. The proportions shown are based on volume and using good quality materials such as sand. **FILPRO** cement can be used with all cement additives and admixtures when used in accordance with manufacturers' recommendations. User should carry out their own testing to ensure the right mix for their specification and requirements. Care should be taken to prevent moisture loss and weather damage of finished work.		

Process after produce this product:

Repair Program 4

Parking Area, Pangsapuri Baiduri, Shah Alam

Target Market of this product:

Impacts on Society, Academia, Government, Industry and Environment

Impact on Society
• FILPRO will contribute in prevent accidents due to the potholes occurrences. This will provide a convenient environment to the society while using the road and provide a better safety condition.
• Introducing FILPRO with environmental - friendly and user-friendly characteristics aids in safeguarding the environment and achieving sustainable society and quality lifestyles.

Impact on Academia
• FILPRO is a new product to be introduced as a road repair material. The outcome of data from this research will generate new findings to the academic world and highly the potential to be published and become a reference for future knowledge.

As FILPRO used in this research is a new concept of the utilization of geopolymer concept as road repair materials, it will become a breakthrough to the academic value and industries' need.

Impact on Government
• FILGAP will also government policies especially in satisfying SDG 9 and 11 requirements and reducing the operation cost or road repair process.

Impact on Industry
• The innovation of FILGAP will become a reference to road repair construction industries in utilizing FILPRO in their product.

Impact on Environment
• FILPRO provides road repair materials that are high workability, fast setting, and high durability as compared to conventional road repair materials. This condition creates a working and effective environmental condition for resilient infrastructure

BUSINESS MODEL FILPRO

KEY PARTNERS
1. Ex Energy Sdn Bhd
2. Petronas Research Sdn Bhd
3. MBSA
4. LLM
5. JKR

KEY ACTIVITIES
1. R&D activities
2. Scale up fabrication system
3. Methodological framework

KEY RESOURCES
INCOM Research Group
CSM Society
UiTM

VALUE PROPOSITION
Innovative sustainable material which utilizes industrial by-product and zero cement (SDG 9)

Special formulation of nano-geopolymer technology (FILGAP) combined with classified filled material (FILPOTH) (SDG 9)

High performance materials for resilient repair and rehabilitation (SDG 11)

FILPRO offers a better solution for pothole problems in Malaysia communities (SDG 11)

CUSTOMER RELATIONSHIP
Act as supplier and provide product support

Word of mouths generation

Trade shows

CHANNELS
Module sale to supplier/tier 1

Seminar and workshops

Training for repair

CUSTOMER SEGMENTS
Construction companies and tier 1 suppliers.

Repair and rehabilitation for infratsructures

COST STRUCTURE
Labor (assembly line workers)
Materials (supplies for manufacturing of repair material)

REVENUE STREAMS
New sustainable and durable repair material for potholes repair and restoration.
Royalty

Impact of Innovation on Target Groups: FILPRO Geopolymer

Innovative/Creative Elements

- **Creation of New/Improved Value/Elements:** FILPRO Geopolymer introduces a road repair material based on advanced geopolymer technology, featuring a DIY concept. It utilizes environmentally friendly materials, offering high workability, fast setting, non-toxic properties, and excellent physical and mechanical characteristics. By using fly ash with high silica (SiO_2) and alumina (Al_2O_3) content, FILPRO reduces CO_2 emissions and converts potentially hazardous waste into valuable products.
- **Simplification/Problem-Solving Elements:** FILPRO is designed to address pothole issues quickly and efficiently. It provides a durable solution, overcoming the shortcomings of conventional repair materials like cold mix asphalt, which often fail under extreme weather conditions. With a quick setting time of less than 10 minutes and no shrinkage problems, FILPRO is an ideal choice for immediate road repairs.

Effectiveness Elements

- **Tangible Benefits:** FILPRO offers high compressive strength (over 80 MPa) and strong bonding strength (over 25 MPa), significantly outperforming commercial repair materials such as cold mix asphalt. This makes it a superior option for long-lasting road repairs.
- **Increased Productivity/Satisfaction:** FILPRO's ability to harden in less than 10 minutes reduces road closure times and disruptions to road users, enhancing productivity and user satisfaction.
- **Revenue Generation (if applicable):** With a cost-effective price (USD 40-50 per m^3) compared to conventional repair materials (USD 50-70 per m^3), FILPRO not only offers cost savings but also creates opportunities for revenue generation by reducing maintenance costs and improving repair quality.

Significant Elements

- **Customer-Friendly Service:** FILPRO simplifies the road repair process with its DIY concept, enabling users to carry out repairs easily and quickly. This reduces waiting times for professional repairs and minimizes disruptions for road users.
- **Time/Cost/Human Resource Savings:** The use of FILPRO reduces the time needed for road repairs, cuts maintenance costs, and minimizes the need for human resources due to its quick setting time and high workability.
- **Achievement of Initiative Objectives:** FILPRO is designed to meet objectives such as reducing road accidents caused by road damage, improving the quality of road repairs with durable and environmentally friendly materials, and lowering long-term road maintenance costs.

Relevant Elements

- **Contribution to Organizational/National Agenda:** FILPRO contributes to national and organizational agendas by reducing CO_2 emissions through the use of fly ash as a primary material, aligning with sustainability and green environment initiatives. Additionally, the product enhances road safety and reduces maintenance costs, supporting the goals of improving national infrastructure.

FILPRO Geopolymer demonstrates significant innovative impact by addressing road repair challenges with a quick, durable, and eco-friendly solution, while offering high economic value and enhancing road safety and user satisfaction.

Publications:

Warid Wazien A. Z. Apandi, N.M. Adesina, A. Alengaram, U.J. Faris, M.A. Tahir, M.F.M. Physico-Mechanical Properties of Geopolymer Mortars for Repair Applications: Impact of Binder to Sand Ratio. Constr. Build. Mater. 2024, 412, 134721

Warid Wazien, A. Z., Mohd Mustafa Al Bakri Abdullah, Mohd Fadzil Bin Arshad, Rafiza Abd Razak, Muhammad Faheem Mohd Tahir, Remy Rozainy Mohd Arif Zainol, Marcin Nabialek, Andrei Victor Sandu, Jerzy J. Wyslocki, Katarzyna Bloch, Characterisation At The Bonding Zone Between Fly Ash Based Geopolymer Repair Materials (GRM) And Ordinary Portland Cement Concrete (OPCC) (2021) (2) 14, 1, 56

Warid Wazien, A. Z., Bouaissi, A., Abdullah, M.M.A.B., Abd Razak, R., Yoriya, S., Mohd Salleh, M.A.A., Rozainy M. A. Z., M.R., Fansuri, H. (2020) Bonding Strength Characteristics of FA-Based Geopolymer Paste as a Repair Material When Applied on OPC Substrate. Appl. Sci. 2020, 10, 3321 (ISI/WOS)

Warid Wazien, A. Z., Al Bakri Abdullah, M. M., Abd Razak, R., Mohd Remy Rozainy, M. A. Z., Mohd Tahir, M. F., & Hussin, K. (2016). Potential of Geopolymer Mortar as Concrete Repairing Materials. *Materials Science Forum*, *857*, 382–387.

Warid Wazien, A. Z., Abdullah, M. M. A. B., Abd Razak, R., Rozainy, M. A. Z. M. R., & Tahir, M. F. M. (2016). Strength and Density of Geopolymer Mortar Cured at Ambient Temperature for Use as Repair Material. *IOP Conference Series: Materials Science and Engineering*, *133*.

Warid Wazien, A. Z., Mustafa, M., Bakri, A., Razak, R. A., Rozainy, M. A. Z. R., Faheem, M., Faris, M. A. (2016). Review on Potential of Geopolymer for Concrete Repair and Rehabilitation, *MATEC Web of Conferences, 01065*, 6–11.

Warid Wazien, A. Z., Abdullah, M. M. A. B., Razak, R. A., Zainol, M. R. R. M. A., & Tahir, M. F. M. (2017). Bond strength mechanism of fly ash based geopolymer mortars: A review. *IOP Conference Series: Materials Science and Engineering*, *267*.

Warid Wazien, A.Z., Abdullah, M. M. A. B., Zainol, M. R. R. M. A., Razak, R. A., & Tahir, M. F. M. (2017). Compressive and bonding strength of fly ash based geopolymer mortar, *AIP Conference Proceeding: Green Construction and Engineering Education for Sustainable Future,* 020058.

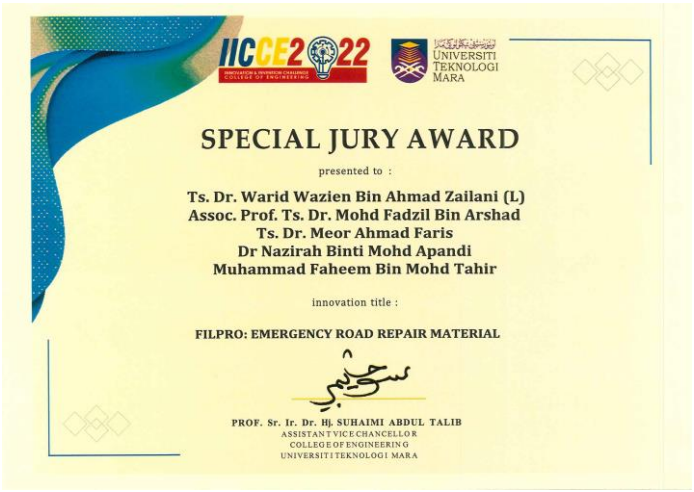
Achievement:

AWARDS
FILPRO

OUTSTANDING INVENTION by:
INTERNATIONAL FEDERATION OF INVENTORS ASSOCIATIONS 2023

ACADEMIQUE D'OR (GRAND AWARD) by:
INNOVATION COMPETITION 2023

SPECIAL JURY AWARD by:
INNOVATION AND INVENTION CHALLENGE 2023



MATERIAL COSTING (FILPOTH)

Materials	FILPOT (weight for 1kg)	FILPOT (RM/kg)	Commercialized Repair Material (SIKA)	Commercialized Repair Material (Cold Mix Asphalt)
Raw OPC	0.2 kg	RM 0.1/kg	SikaTop-121 MY RM 125/kg	Cold Mix: RM 32/kg
Fine aggregates (River sand)	0.4 kg	RM 0.0072/kg		
Coarse aggregates (Granite/Limestone)	0.4 kg	RM 0.016/kg		
Total	1 kg	RM 0.1232/kg		

RETURN OF INVESTMENT (ROI)
5 Years Operation

Year of Operation	0	1	2	3	4	5	Total
Benefits ($ mil)							
Total Benefits (Sales)	0	600,000	630,000	642,000	654,000	660,000	3,186,000
Costs ($ mil)							
Development	300,000						300,000
Pre-launch Marketing	-						-
COGS (20%)	-	100,000	105,000	107,000	109,000	110,000	531,000
Salary and Expenses		396,000	414,000	421,200	428,400	432,000	2,091,600
Total Costs	300,000	496,000	519,000	528,200	537,400	542,000	2,922,600
Cashflow ($ mil)	(300,000)	104,000	111,000	113,800	116,600	118,000	563,400
Undiscounted Cumulative Cashflow	(300,000)	(196,000)	(85,000)	28,800	145,400	263,400	
Discount Factors							
Discounted Cash Flows ($ mil)	(RM300,000)	RM90,435	RM83,932	RM74,825	RM66,868	RM59,667	RM74,525
Cumulative Discounted Cash Flows (DCF)	(RM300,000)	(RM209,565)	(RM125,633)	(RM50,808)	RM15,859	RM74,525	

NPV without Initial Investment
RM374,525
RM374,525

Net Present Value	RM74,525
IRR	24.83%
Discount rate	15%

SWOT ANALYSIS

S

STRENGTHS

• A well -balanced team member in contributing knowledge is gathered.
• A budget is required for the purchase of raw materials and chemicals. This project does not require the procurement of expe nsive equipment. Frequent monitoring of the cost of raw materials and chemicals to ensure no financial interruption.
• Researchers' experience in conventional ettringite formation in repair materials leads to a high success rate.
• Three FILPRO precursors are proposed to lower the risk of the proposed research work.

W

WEAKNESSES

• The suitable formulation of each system must be obtained before the recommendation of the reaction mechanism and conclusion on the efficiency of each system. The challenge of this work is to understand and obtain data for the in -situ reaction that take s place during the formation of Chemokinesis Ettringite from the beginning when the raw materials are mixed until the formation of ha rd solid. Careful sample preparation and monitoring are acquired.
• Schedule overruns are most likely to occur due to the delay in the analysis as a result of breakdown/maintenance of characterization tools, trial, and error experimental work, and validation of experiment data (if any). To cater to schedule overruns, an average of 6 months is allocated for each milestone. Frequent monitoring of project schedule to make sure works are done w ithin the planned schedule.

O

OPPORTUNITIES

• FILPRO offers an advancement in cement technology and increases the acceptance and applicability in industries, especially in the construction industry.
• Strategic collaboration with industry to achieve industry's aim.

T

THREATS

• Strong confidence in the conventional cementitious binder in the construction industry due to long -term history.
• Long-term reliability and applicability are yet to be determined. Continuous research is acquired to profit usefulness.

Collaboration By:

FILPRO™

Emergency Road Repair Materials

Main Inventor

Collaborators

Video Link:

https://qr.page/g/F5UtxOA2bh