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Scientific paper
ISSN 0351-9465, E-ISSN 2466-2585
https://doi.org/10.62638/ZasMat1044

Zastita Materijala 65 (2)
360- 370 (2024)

Serviceability performance of fibre reinforced no fine concrete pavement

ABSTRACT

The massive development of the construction industry demands sustainability, and the studies on No Fines Concrete (NFC) will support sustainable development in the field of transportation and highway industry. It is the key requirement of all developing countries like India in order to satisfy three main criteria namely sustainability, serviceability and feasibility in addition to its performance. Application of NFC pavement is itself a sustainable method to manage and discharge the retaining stormwater during heavy floods. Fibre Reinforced No Fine Concrete (FRNFC) was considered, with findings suggesting that the inclusion of fibres has minimal impact on strength characteristics and only marginally reduces the permeability of NFC. However, NFC pavements require regular maintenance to prevent clogging of pores with dust, sediments, and debris, which impairs water flow. A 2 m x 2 m span real-time FRNFC pavement was cast and subsequently subjected to assessment of its serviceability performance. The study examines the performance of FRNFC under clogging and suggests rehabilitation methods to reinstate infiltration capacity. Pressure wash combined with vacuum sweep shows the highest Drainage Efficiency Restoration (DER), maintaining drain ability from 99% to 90% after 12 cycles. Routine pressure wash monthly and vacuum sweep yearly are recommended for proper pavement serviceability and effective stormwater runoff mitigation.

Keywords: *No fine concrete, fibre reinforcement, serviceability, clogging, drainage efficiency*

1. INTRODUCTION

The increase in the infrastructural development and urbanization of several countries around the world resulted in decreasing the Earth's overall permeability. It also encounters serious environmental effects such as global warming, reduction in groundwater recharge, water pollution, and water stagnation during heavy rainfalls. Poor drainage with the impermeable surface will result in difficulties in using road transport facilities and accessing the basement of surrounding buildings in heavy rainfall prone areas. Installation of NFC pavement replacing the conventional impervious one is an efficient and sustainable solution to avoid flooding frequently. A numerous study has been conducted to evaluate the material properties of NFC. This study extensively made the effort of adding fibre to NFC thereby increasing its durability without compromising its structural or hydraulic behaviour. FRNFC pavement system differed from conventional rigid concrete pavement systems by their complexity of inherent and flexible porosity along with multi-layer arrangements. The application of NFC is restricted for light loading conditions such as parking lots and sidewalks of residential areas [1]. The prototype developed was proposed to serve as a highway shoulder, where the runoff due to high precipitation can be drained. This can highly reduce the requirement of stormwater control structures constructed specially for highway runoff. When an FRNFC pavement is designed to be a highway shoulder, it should survive the wheel loadings from invading truck. Nevertheless, the incorporation of polypropylene fibres is aimed at enhancing durability aspects such as abrasion and resistance to freeze-thaw cycles, which are ongoing considerations for practical application. Pervious or NFC pavements are categorized under rigid pavement design. Still, there are some fundamental differences between them such as strength, stiffness, subbase and subgrade [2].

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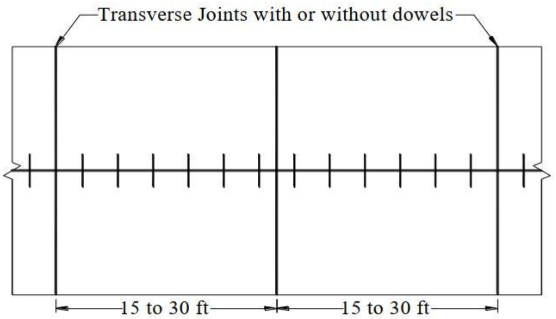
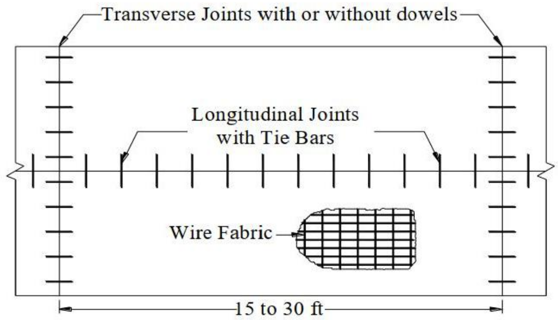
Paper received: 26. 02. 2024.
Paper corected: 13. 03. 2024.
Paper accepted: 17. 03. 2024.
Paper is available on the website: www.idk.org.rs/journal

2. TYPE OF PAVEMENTS

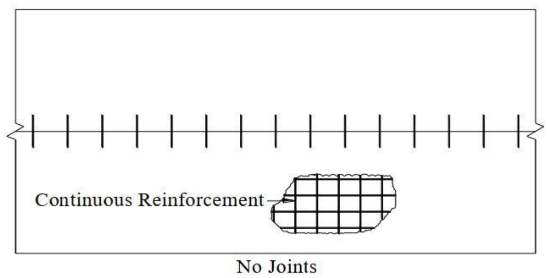
The pavements are the structural elements used in highway applications with the primary function of transmitting load to the subbase and underlying soil. Pavements are categorized into three major types including flexible or asphalt pavement, rigid or cement concrete pavement and composite pavements. The composite pavements are constructed with a combination of flexible (top layer) and rigid (bottom layer) pavements. Hot mix asphalt and Portland cement concrete are generally used in the construction of composite pavements. Rigid pavements are further classified based on the joints and reinforcement as shown in Figure 1.



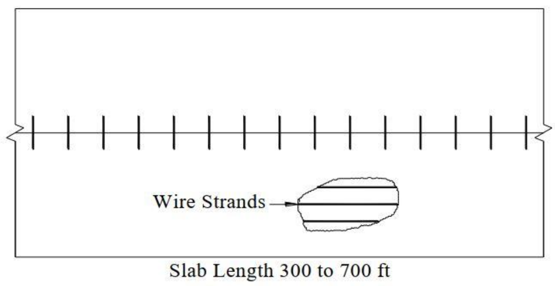
a) JPCP (Jointed Plain Concrete Pavement



b) JRCP (Jointed Reinforced Concrete



c) CRCP (Continuously Reinforced Concrete Pavement)



d) PCP (Prestressed Concrete Pavement)

Figure 1 Types of Rigid Pavement
Slika 1 Tipovi krutih kolovoza

A traditional rigid pavement consists of three layers, concrete, subbase and subgrade or soil strata as shown in Figure 2. The traffic volume and the expected pavement loading are the key factors for designing the depth of the concrete and subbase layer. The subbase layer was latterly introduced for resisting the high traffic volume and pavement loading, it is also used to reduce the water thrusting of the concrete layer by the subgrade.

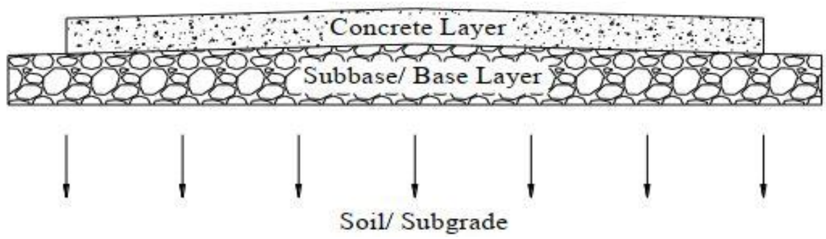


Figure 2 Cross section of Rigid Pavement
Slika 2 Poprečni presek krutog kolovoza

NFC pavements are generally considered under Low Impact Development (LID) techniques, which practices the natural infiltration and control the runoff volume [3]. For NFC pavement, the design depth of the subbase is larger than that of traditional rigid pavement. And usually, the sub-base is not compacted as much tight as practising for normal rigid pavement. This is to increase the volume of storage packets (voids) and thereby increasing the retention period to support natural infiltration of stormwater [4]. An additional property of noise absorption by these types of pavements can serve as a sustainable solution for the reduction of noise pollution during heavy traffic conditions [5].

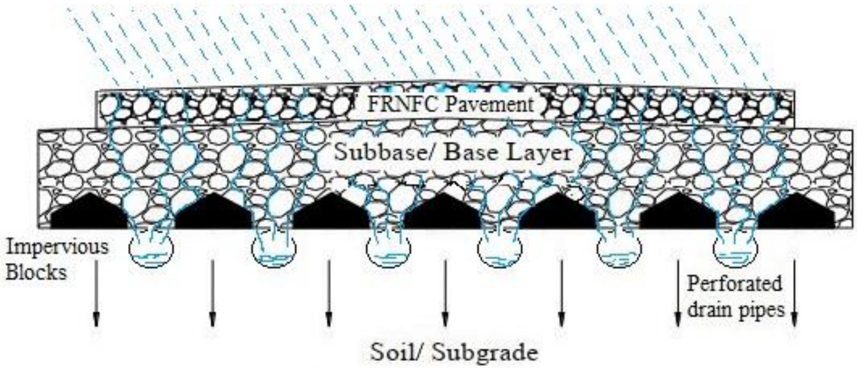


Figure 3. Cross section of Proposed FRNFC Pavement

Slika 3. Poprečni presek predloženog FRNFC kolovoza

Figure 3 shows the cross-section of the proposed FRNFC pavement, with increased subbase thickness and perforated drainpipes separated by impervious blocks just below the subbase. These blocks are used to break the infiltration link to the subgrade (underlying soil) which affects the bearing capacity of soil and cause failure to the pavement.

2.1. Subgrade

The subgrade is also known as formation level, i.e., the natural layer present underneath the pavement to be constructed. The characteristics of a given soil are taken before the review of the soil profile for determining the settlement. The investigation of the subgrade is much important before preparation for permeable pavement since the infiltrated water has an adverse effect on both the pavement and subbase. The values of modulus of elasticity and Poisson's ratio of a particular soil varies with respect to the degree of saturation and drainage condition [6]. Preferably for FRNFC pavements also subgrade with a higher drainage ratio is chosen to increase the efficiency of stormwater runoff management. Table 1. gives the values of the modulus of elasticity and Poisson's ratio based on the soil's drainage condition.

Table 1. Moduli of elasticity and Poisson's ratio of soils (Coduto,1994)

Tabela 1. Moduli elastičnosti i Poissonov odnos tla (Coduto,1994)

Soil Type		Modulus of elasticity (GPa)	Soil Type	Poisson's ratio
Clay (Undrained condition)	Soft	0.0015-0.01	Saturated soil (Undrained condition)	0.50
	Medium	0.005-0.05		
	Stiff	0.015-0.075		
Clay (Drained condition)	Soft	0.0003-0.0015	Partially saturated clay	0.30-0.40
	Medium	0.0005-0.0035		
	Stiff	0.0012-0.02		
Sand (Drained condition)	Loose	0.01-0.025	Loose sand (Drained condition)	0.30-0.40
	Medium dense	0.02-0.06	Dense sand (Drained condition)	0.10-0.30
	Dense	0.05-0.1		
Sandstone	-	7.0-20.0	Sandstone	0.25-0.30
Granite	-	25.0-50.0	Granite	0.23-0.27

In drained condition, the rate of drainage is greater than the infiltration rate and for the undrained condition, the rate of drainage is less than the infiltration rate. The drainage rate is the function of permeability coefficient or hydraulic conductivity. For example, sand and gravel hold drained condition easily as the coefficient of permeability is high, and clay soils hold in undrained condition often due to less coefficient of permeability. Generally, subgrade with a higher drainage ratio is preferred for rigid pavements to reduce the effect of water thrusting which affects the soil stability with respect to time.

2.2. . Subbase

Subbase is one of the layers of pavement laid over the subgrade, specially designed for bearing the load from the pavement and distribute it to the soil strata. The subbase quality is highly important to increase the serviceability of the pavement. Generally, natural aggregates of size not less than 20 mm are used for the subbase. The thickness of the subbase is obtained from Table 2. Since the proposed pavement design is adopted for highway shoulder application, the thickness of 10" (0.25 m) is taken for this study. However, Subbase does not bring any structural strength to the pavement but distributes the load uniformly to the subgrade. Generally bounded subbases are recommended for rigid pavements in design guides, for permeable rigid pavements unbounded subbase are preferred. The thickness of subbase and concrete pavement does not change with the subgrade strength as in the case of flexible pavement. Still, the material selection, proper design and effective construction is very much important for the long-term serviceability of the pavement.

Table 2. Thickness of Subbase

Tabela 2. Debljina podloge

S. No.	Road Application	Standard Thickness (in)
1	Garden Pathway	3 – 4
2	Driveway and public foot path	4 – 6
3	Heavy used Roadways	6 – 9
4	Highway	> 10

3. FRNFC PAVEMENT

The construction of given pervious or FRNFC pavement systems involves 3 layers (bottom quarter, middle half and top quarter) with an assumption of the faultless bond between the layers [7-10]. The porosity of these three sections varies with the time period, and an average porosity is finally considered as the system porosity. The porosity of the top quarter changes with respect to time due to the clogging effects and reduces the system porosity. And the bottom quarter porosity varies with the selection of subgrade (coarser subgrade permits higher discharge rate) [11]. Whereas the porosity of the middle half remains the same and is influenced by poor placement practicing, which can be enhanced during pavement casting.

The distribution of wheel load is uniform to the area under the slab. The load on the slab is transmitted through beam action, and hence with sufficient beam strength, the pavement can withstand any areas within adequate support and localize subgrade failures [12]. Figure 4 illustrate the wheel load distribution of concrete pavements.

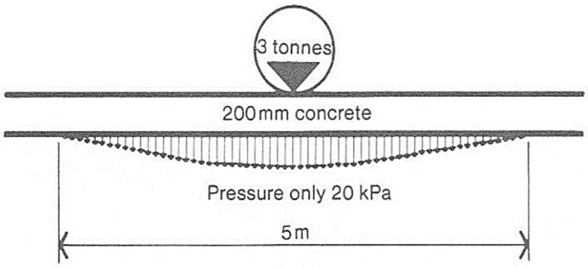


Figure 4 Wheel load distribution of concrete pavements

Slika 4 Raspodela opterećenja na točkove betonskih kolovoza

3.1. Highway Shoulders

An adjacent portion connected with highway specially meant for parking the trucks or any emergency drives, and to provide support for the subbase and pavement along lateral direction [13]. Thus, shoulders are subjected to similar loading as that of the main pavement. FRNFC pavement with thickness ranging from 200 to 300 mm is considered to be effective for replacing highway shoulders based on the usage intensity [14-15].

3.2. Site Preparation and Placement

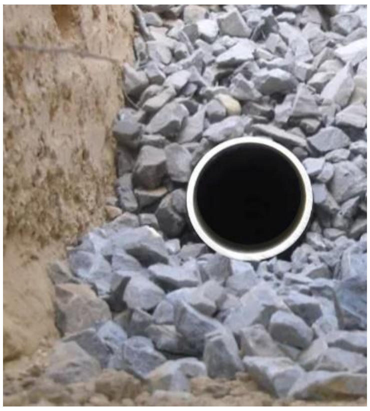
Before the placement of pavement, the subgrade should be maintained in moist condition with no standing water. The excess water present in the subgrade can eradicate the binder from the bottom portion of the pavement. High porosity without compromising strength and durability is the main target of the NFC pavement, care must be taken to avoid the premature drying of the concrete mixture [16]. The concrete placement with high evaporation rates must be avoided to reduce the chance of loss in water content. The factors like high voids content and less w/c ratio support the rapid drying of mixtures followed by a reduction in strength and durability.

Site preparation and placement includes preparation of subbase and pavement placement. Figure 5 shows the preparation of subbase including the a) excavation for subbase preparation, b) arrangements for perforated pipes and impervious block, c) filling of aggregates as subbase and d) cross-section of perforated pipe connected to side drain to collect runoff water. Whereas Figure 6 illustrates the transportation and placement of FRNFC pavement in the site.

(a) Excavation for subbase

(b) Arrangements of Perforated pipes

(c) Filling of Subbase



(d) Pipe Cross section

Figure 5. Preparation of Subbase

Slika 5. Priprema podloge

(a) Transportation of fresh concrete

(b) Placement of FRNFC Pavement

Figure 6 Pavement Placement

Slika 6 Postavljanje kolovoza

3.3. Pavement Configuration

The dimension of the slab is taken as 6.5’ x 6.5’ (2 m x 2 m) and the thickness of the FRNFC pavement, subbase and subgrade layers were considered to resemble a typical roadway pavement thickness. There is a difference observed between traditional concrete and FRNFC in the values of stiffness, compressive strength and flexural behaviour. Generally, for pavements, the stiffness of subbase and subgrade are also taken into consideration as given in Table 3.

Table 3. Material Properties obtained from laboratory testing

Tabela 3. Svojstva materijala dobijena laboratorijskim ispitivanjem

Material/Layer	Youngs Modulus E (Mpa)	Poisson's ratio, n_u (no units)	Density, ρ kg/m^3)
Polypropylene Fibre	4.0 - 4.5	0.4	910
FRNFC Slab	18875	0.2	1875
Subbase	5000	0.2	1542
Subgrade	200	0.4	1430

3.4. Thickness Design

An FRNFC slab model of thickness 8" (0.2 m) was cast in the laboratory parking area. The pavement was placed over an unbound subbase of thickness 10" (0.25 m) prepared by aggregates of size 20 mm. A partially saturated with the undrained condition is taken as a subgrade with a thickness of 39" (1 m) as shown in Figure 7. The design depth of the subbase used for an FRNFC pavement is usually larger than that of a traditional impervious rigid pavement [17]. And also, the subbase is not compacted as much tight as practising for normal rigid pavement. This is to increase the volume of storage packets (voids) and thereby increasing the retention period to support natural infiltration of stormwater [18-19].

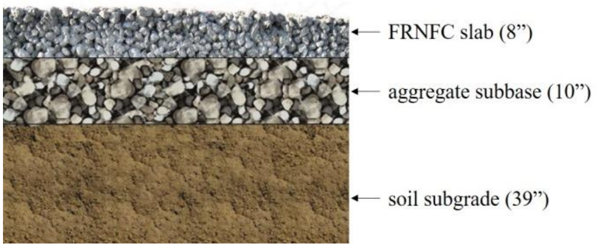


Figure 7 Pavement Thickness Design

Slika 7 Projektovanje debljine kolovoza

3.5. Drainage Design

The infiltration of water subsequently affects the stability and bearing capacity of the subbase and subgrade, which in turn affects the serviceability of the pavements. Figure 8 shows a typical cross-section of drainage design of the proposed FRNFC pavement specially used to break the infiltration link to the subgrade (underlying soil), with perforated drainpipes separated by impervious blocks just below the subbase. The collected stormwater from the perforated drainpipes is directed to common outfall drain from where they can be sent to treatment units.

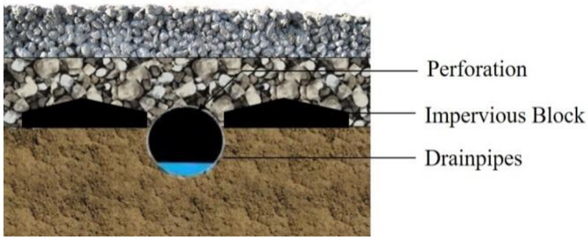


Figure 8 Drainage Design

Slika 8 Dizajn drenaže

4. SERVICEABILITY BEHAVIOUR

No fines concrete is most commonly known as sustainable concrete that helps in stormwater mitigation, pollutants load reduction, temperature mitigation, noise absorption, air quality improvement, etc., [20]. Besides these benefits, their serviceability is likely to be affected by several factors like clogging and less surface abrasion resistance. However, the fibre reinforcement was incorporated to improve its abrasion resistance [21]. The performance of FRNFC under the clogging effect was examined and the change in infiltration capacity of the specimens was discussed. To reinstate the infiltration capacity, certain rehabilitation methods were suggested, and their efficiencies were discussed [22]. This study provides security for the investment made on no fines concrete; the pavement must serve for a minimum service life by providing resistance against all these factors.

4.1. Clogging

NFC pavements have a high chance of clogging after every rainy event. Clogging is one of the significant issues associated with the serviceability of NFC pavements as it reduces its infiltration capacity. It is also considered to be one of the main restrictions against the practical application of pervious pavements [23]. Clogging takes places due to the deposition of dust, sediments, debris, and other inorganic particles over the pores on the pavement surface during stormwater runoff.

The slab specimens cast for determining the infiltration capacity, are subjected to clogging by allowing dirt muddy water containing different types of clogging materials such as sand, clay, and silt as shown in Figure 9. Twelve cycles of clogging and cleaning were carried out and its drain ability was tested after every clogging (reduced infiltration) and cleaning cycle (recovery infiltration).

a) Test Setup

b) Specimen after clogging

Figure 9. Clogging test on FRNFC Pavement

Slika 9. Test začepljenja na FRNFC kolovozu

4.2. Rehabilitation Methods

NFC pavements need proper maintenance or rehabilitation since dust, sediments, debris, and other inorganic particles get deposited into the pores of the pavement surface and clog the water flow. Periodic removing of surface sediment particles prevents their deeper penetration inside the concrete matrix and thereby affecting the drain ability of the pavements. The FRNFC specimens subjected to clogging test are then rehabilitated to restore the infiltration rate by standard cleaning methods such as pressure wash (wet cleaning), vacuum sweep (dry cleaning), and combined method [24].

Pressure Wash

Pressure wash technique can be adopted to remove the surface clogging by applying a concentrated water using power nozzle sprayer over the surface of the FRNFC pavements after scrubbing to get out the debris as shown in Figure 10. This pressurized water from the nozzle will wash off all the surface dirt by weakening the bond between the concrete and clogged particles. Small particles will penetrate deep into the concrete matrix and reaches the subbase layer, gets deposited on the aggregate reservoir. This method is highly recommended for high load of sediments or debris.

Figure 10. Pressure Wash

Slika 10. Pranje pod pritiskom

Vacuum Sweep

The surface of the FRNFC pavements can be subjected to a dry vacuum sweep method annually to dislodge the hidden clogged particles and debris. It consists of three units, a blower, suction tube, and a hopper. This method of cleaning is considered to be more effective than pressure wash which requires plenty of water to wash off the debris from the surface, whereas vacuum sweep implements a simple tool of vacuum cleaner to removes the debris off from the pavement surface and dump it into a hopper as shown in the Figure 11.

Figure 11. Vacuum sweep

Slika 11. Vakuumsko čišćenje

The silt carried by the runoff water plugs into the concrete matrix, on saturated conditions the silt starts bulged and gets sticky to the matrix. Hence, this method is usually carried when the pavement is in dry condition, as the silt loosen its grip with the matrix by shrinking and get sucked by the suction tube.

Combined Method

This combined method of cleaning FRNFC pavement includes a vacuum sweep followed by a pressure wash, which produces the best results in improving the efficiency of infiltration after a clogging cycle. The clogged debris get dislodged from the interconnected voids, by using pressure wash and vacuum sweep once after drying the pavement simultaneously.

4.3. Drainage Efficiency Restoration

In recent days, the construction of pervious pavement attracts the attention of the engineers mainly to prevent splashing and to control erosion. Thus, the porous pavement with a storage reservoir to collect the surface runoff should be maintained appropriately for higher drainage efficiency. The effects of clogging and different methods of cleaning for 12 cycles on the infiltration rate of the FRNFC pavement by double-ring infiltrometer test setup is given below in Table 4 and graphically shown in Figure 12.

Table 4. Drainage Efficiency Restoration

Tabela 4. Obnova efikasnosti drenaže

Cycle	Pressure Wash			Vacuum Sweep			Combined Method		
	Infiltration rate, I (cm/sec)		DER	Infiltration rate, I (cm/sec)		DER	Infiltration rate, I (cm/sec)		DER
	Clog	Clean	%	Clog	Clean	%	Clog	Clean	%
0	-	0.291	-	-	0.291	-	-	0.291	-
1	0.223	0.261	89.77	0.223	0.276	94.99	0.223	0.287	98.63
2	0.222	0.257	88.35	0.222	0.274	94.16	0.222	0.281	96.56
3	0.222	0.252	86.72	0.222	0.271	93.28	0.222	0.278	95.53
4	0.220	0.249	85.64	0.220	0.269	92.44	0.220	0.273	93.81
5	0.218	0.248	85.37	0.218	0.266	91.27	0.218	0.269	92.44
6	0.215	0.247	84.85	0.215	0.264	90.59	0.215	0.268	92.10
7	0.212	0.241	82.93	0.212	0.259	88.85	0.212	0.266	91.41
8	0.210	0.241	82.80	0.210	0.258	88.67	0.210	0.265	91.07
9	0.208	0.237	81.58	0.208	0.257	88.28	0.208	0.264	90.72
10	0.205	0.236	81.11	0.205	0.255	87.63	0.205	0.263	90.38
11	0.205	0.235	80.76	0.205	0.251	86.25	0.205	0.262	90.03
12	0.201	0.233	80.07	0.201	0.247	84.88	0.201	0.261	89.69

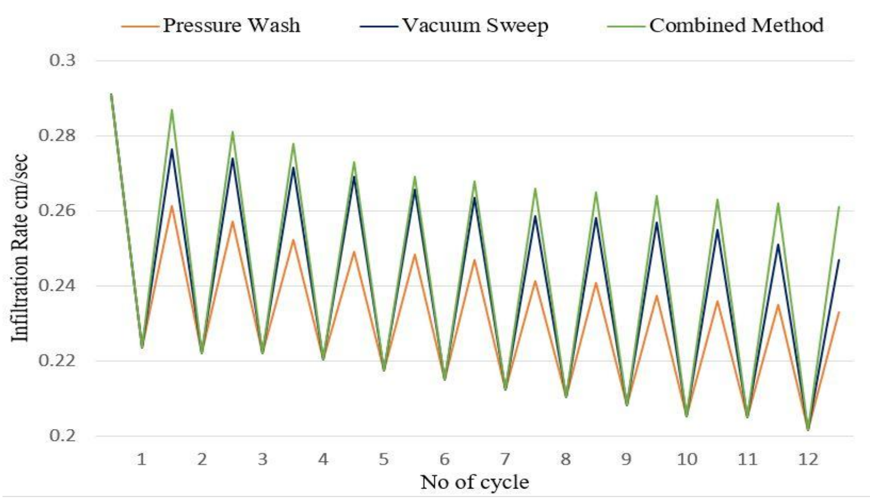


Figure 12. Drainage Efficiency Restoration

Slika 12. Obnova efikasnosti drenaže

The selection of the rehabilitation method highly depends on the clogging percentage and sediment characteristics. Both pressure wash and vacuum sweep combinedly produce the maximum Drainage Efficiency Restoration (DER) from 99% (first cycle) to 90% after 12 cycles of clogging and cleaning. Whereas pressure wash retains drain ability from 90% (first cycle) to 80% after 12 cycles and vacuum sweep retains drain ability from 95% (first cycle) to 85% after 12 cycles.

From the test results, the clogging cycle reduces the rate of infiltration of FRNFC pavement by about 73.6% and it is suggested to routine pressure wash at a frequency of monthly once and vacuum sweep at a frequency of yearly once to ensure proper serviceability of the pavement, to achieve max DER % and effective stormwater runoff mitigation.

4.4. Cost Benefit Analysis

No fines concrete pavements are constructed to support the soil and water conservation practices. The replacement of conventional impervious asphalt pavements by pervious FRNFC pavements would increase the infiltration capacity and supports groundwater recharges and thereby reducing the stormwater runoff. Hence, a cost-benefit analysis is highly essential to answer the question, ‘Whether FRNFC is a cost-effective alternative or not?’.

Table 5. Construction and Maintenance cost comparison for 1 m^2

Tabela 5. Poređenje troškova izgradnje i održavanja za 1 m^2

Particulars	Frequency in 20 years	FRNFC Pavements (₹)	Frequency in 20 years	Asphalt Pavements (₹)
Installation	1	6000	1	4000
Drainage Design	1	450	0	0
Vacuum Sweep	20	15 x 20	0	0
Pressure Wash	240	5 x 240	0	0
Restore Permeability	5	65 x 5	0	0
Crack Sealing	0	0	20	10 x 20
Seal Coat	0	0	5	750 x 5
Stripping	0	0	1	115 x 1
Patching	0	0	5	5 x 5
Surface Replace	0	0	1	1175 x 1
Construction Cost	-	6450	-	4000
Maintenance Cost	-	1825	-	5265
Total Cost per 1 m2	-	8275	-	9260

Detailed cost comparison between conventional impervious asphalt pavements and pervious FRNFC pavements including the construction and maintenance cost for a unit square meter is evaluated and discussed in Table 5. The serviceability of FRNFC pavement is assumed to be 20 years [25].

The installation of pervious pavements by replacing the existing impervious one will not be initially considered as economical, since it also includes the demolition cost. However, counting the benefits and environmental sustainability obtained over time from installation will make it cost-effective. From the above analysis, it is clear that the initial cost required for the construction is high for pervious FRNFC pavements comparing to the impervious Asphalt pavements. This is because FRNFC requires a large amount of excavation and additional design for proper drainage to improve its durability. The base layers in FRNFC pavements are designed to not only offers structural stability but also to assist the infiltration process. While considering the maintenance requirement of Asphalt pavements over the service life it cost higher (almost three times) than the FRNFC pavements. Asphalt pavement includes the cost for crack sealing, seal coat, stripping and patching works whereas FRNFC only requires periodical pressure washing and vacuum sweeping to maintain its drain ability.

Generally, Asphalt pavements are with high surface tension and thereby highly pretentious by temperature, weathering, and minimum geographical stress (ground uplift, earthquakes and swallet). Thus, any difference in stress easily propagates cracks in asphalt pavement and requires regular maintenance to ensure safe drives. This makes asphalt over its service period an expensive choice comparing FRNFC pavements, which have an additional provision for stormwater management.

5. CONCLUSION

The total depth of FRNFC pavement is divided into three layers (top quarter 2”, middle half 4” and bottom quarter 2”). The porosity of these three layers varies, and an average is finally considered as the system porosity. Thus, to increase the overall system porosity of given pervious pavements, each of the three layers must follow different strategies.

- The top quarter porosity changes to time due to the clogging effects and can be recovered, and the efficiency can be restored by practising a few rehabilitation techniques like pressure wash, vacuum sweep, and combined method.
- The bottom quarter porosity varies with the selection of subgrade and is boosted by placing the pervious pavement over a coarser unbounded subgrade which permits a higher discharge rate.
- The middle half porosity remains the same and is influenced by poor placement practising, which can be enhanced during casting.

The infiltration of water to the subgrade subsequently affects its stability and bearing capacity. The proposed FRNFC pavement implements a specific drainage design to break the infiltration link to the subgrade, with perforated drainpipes and impervious blocks just below the subbase. The collected stormwater is directed to a common outfall drain from where it can be sent to treatment units.

From the detailed study of the clogging effect on FRNFC, it is suggested to follow a routine pressure wash at least once a month followed by an annual vacuum sweep to ensure proper drainability of the pavement. And from a cost-benefit analysis, construction of FRNFC pavement over conventional impervious asphalt for a parking lot of ½ acre would save about ₹ 20,13,310 over a service life of 20 years. This makes FRNFC pavement a cost-effective replacement for impervious asphalt pavement.

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IZVOD

MOGUĆNOST UPOTREBE PERFORMANSE OBLOGA OJAČANOG VLAKNIMA BEZ FINOG BETONA

Masivan razvoj građevinske industrije zahteva održivost, a studije o betonu bez finog kamenca (NFC) će podržati održivi razvoj u oblasti transporta i industrije autoputeva. To je ključni zahtev svih zemalja u razvoju kao što je Indija kako bi se zadovoljila tri glavna kriterijuma, a to su održivost, upotrebljivost i izvodljivost, pored svog učinka. Primena NFC kolovoza je sama po sebi održiva metoda za upravljanje i ispuštanje atmosferske vode koja se zadržava tokom velikih poplava. Razmatran je beton ojačan vlaknima bez finog betona (FRNFC), sa nalazima koji sugerišu da uključivanje vlakana ima minimalan uticaj na karakteristike čvrstoće i samo neznatno smanjuje propustljivost NFC-a. Međutim, NFC kolovozi zahtevaju redovno održavanje kako bi se sprečilo začepljenje pora prašinom, sedimentima i ostacima, što otežava protok vode. FRNFC kolovoz u realnom vremenu raspona 2 m x 2 m je izliven i naknadno podvrgnut proceni performansi njegove upotrebljivosti. Studija ispituje učinak FRNFC-a pod začepljenjem i predlaže metode rehabilitacije za ponovno uspostavljanje kapaciteta infiltracije. Pranje pod pritiskom u kombinaciji sa vakuumskim čišćenjem pokazuje najveću restauraciju efikasnosti drenaže (DER), održavajući sposobnost drenaže od 99% do 90% nakon 12 ciklusa. Rutinsko pranje pod pritiskom mesečno i čišćenje usisivačem godišnje se preporučuju za ispravnu upotrebljivost kolovoza i efikasno ublažavanje oticanja atmosferskih voda.

Ključne reči: *Bez finog betona, vlaknasta armatura, upotrebljivost, začepljenje, efikasnost drenaže*

Naučni rad
Rad primljen: 26. 02. 2024.
Rad korigovan: 13. 03. 2024.
Rad prihvaćen: 17. 03. 2024.
Rad je dostupan na sajtu: www.idk.org.rs/casopis