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Study on green concrete (porous concrete) sustainability to support sustainable construction in Indonesia

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***Abstract**. Currently, the implementation progress of green concrete (porous concrete) is still very slow. The sustainable construction launched by the government has also not received a positive response from the construction sector. Green Open Spaces (RTH) and urban spatial planning in Indonesia have not accommodated the type of water-friendly pavement (porous concrete). Buildings that must meet the 30% of Green Base Cooeficient (KDH) also have not included the criteria for water-friendly concrete pavements. From the results of the Multi-Dimensional Scaling (MDS) analysis using Rapfish-R, it is known that the sustainability status of porous concrete is at a score of 71.9 (sufficiently sustainable). There are no leveraging factors from the ecological dimension because this pavement is proven to positively impact the environment, especially for groundwater reserves. Leverage from economic dimensions, i.e., added value for customer, durability, and installation costs. Institutional dimensions, i.e., application of eco-labels, product standards, and criteria for RTH and KDH. Socio-technical dimension, i.e., public understanding and perception, certification scheme, the role of media, design, and maintenance. From these leveraging factors, the strategy and roadmap for supporting sustainable construction related to green concrete applications can be formalized.*

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INTRODUCTION

Environmentally friendly concrete can be viewed from two aspects: the concrete production process and application. This research is focused on its application. Several types of concrete are categorized as green concrete, including porous concrete. This type of concrete can help accelerate the infiltration of rainwater into the ground so that it can increase groundwater reserves and reduce the risk of flooding. It also can be used in city parks to support the function of city parks as a hydrological function (Harbowoputri 2018). Other uses such as for pavements, open fields, parking areas, low-load roads, waterways, slope reinforcement, and erosion control (Kevern 2011). Porous concrete pavement is the best solution to reduce the problem of waterlogging, reduce environmental temperature, reduce noise, and improve water quality.

However, its use is still very low due to a lack of understanding of the benefits obtained. Even the United States Environmental Protection Agency (USEPA) has determined porous concrete pavements as the best water runoff management standard that can be used for parking areas, low-load roads, and sidewalks (Elizondo-Martínez et al. 2019). The concept of urban concrete pavements in Indonesia is not yet environmentally friendly or in favor of water absorption. For example, pedestrians in city parks, shopping centers, sidewalks, parking areas, and roads still use paving block pavement, asphalt, or solid concrete. With high rainfall, of course, this can cause puddles or flooding problems because the drainage load is not able to accommodate rainwater runoff (Harbowoputri 2018).

The application of porous concrete needs to be supported by policies and regulations from the central and local governments. Regulations related to the use of concrete materials and water absorption functions include Law number 26/2007 concerning spatial planning, Government Regulation number 16/2021 concerning buildings, Government Regulation number 21/2021 concerning spatial planning, Ministry of Public Works Regulation (PUPR) number 02/2015 concerning green buildings, Presidential Regulation number 12/2021 concerning procurement of government goods and services, Ministry of Public Works Regulation (PUPR) number 5/2008 concerning guidelines for the provision and use of green open space in urban areas (PUPR 2008), DKI Governor Regulation number 135/2019 concerning building planning guidelines, Depok City Regulation number 3/2018 concerning the Depok Regional Spatial Plans (RTRW). Procurement criteria in the construction sector also do not include criteria related to environmentally friendly building materials (Hardiani 2016).

The use of green concrete (porous concrete) in the construction sector is still experiencing various obstacles. It is necessary to analyze the sustainability of the use of porous concrete in Indonesia in terms of the ecological, economic, socio-cultural, and institutional dimensions. The sustainability analysis in question is the Multi Dimensional Scaling (MDS) method using the Rapid Appraisal for Fisheries (RAPFISH) application through the R-Gui program. The use of the MDS method is quite effective for assessing the sustainability status in a multidimensional manner, namely related to ecological, economic, social, and institutional aspects (Fauzi and Anna 2002).

METHOD

Location and Research Time

This research was conducted from July 2021–June 2022 with the focus of research being carried out in three green open spaces that have used concrete pavement with porous concrete, i.e., GBK Senayan Jakarta, Army Headquarters Field and Depok Town Square (Figure 1).

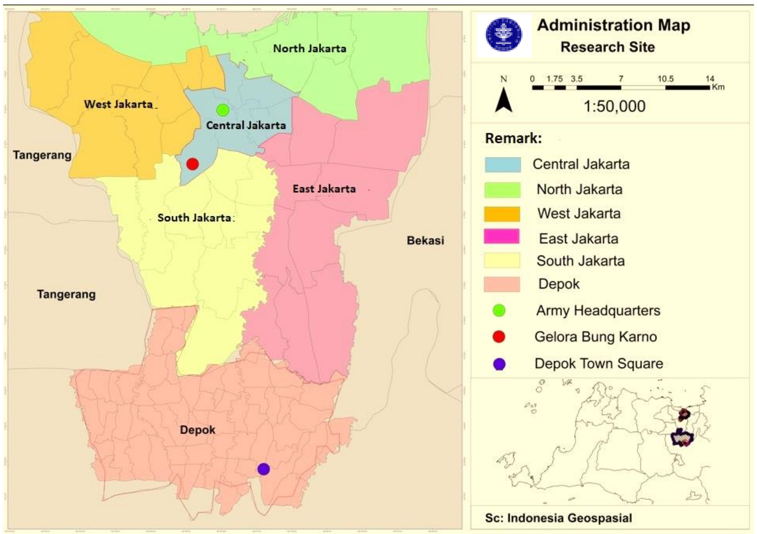

Figure 1 DKI and Depok administration map

Collection Data Method

The data collection process obtained from the results of interviews with construction experts or practitioners and related parties, including Dinas PUPR, Indonesian Cement Association (ASI), Eco-label Verification Institute (LVE), producers and users of porous concrete to determine sustainability aspects that became the focus of discussion and field survey at the research site. Other supporting data is obtained through literature studies from relevant agencies or from various other sources, such as the publication of statistical data by the Central Statistics Agency and Bappeda, Regional/National Regulations, and data obtained from concrete producers and related agencies/agencies.

Data Analysis Method

Policy Analysis in the Implementation of Green Concrete

Desktop analysis by reviewing all regulations and strategies related to environmentally friendly building materials national and regional development strategies. Policy analysis related to environmentally friendly buildings or green buildings, green open space (RTH) policy, and green base coefficient (KDH), which is focused on the implementation of porous concrete. The analysis starts from policies at the national level, government regulations, ministerial regulations to regional/governor regulations, and interviews with practitioners and concrete producers.

Runoff Analysis of Concrete Pavement

Discharge and volume of runoff water from several types of concrete pavement and without pavement using the formula:

$$I = \frac{Ch}{24}\left(\frac{24}{24 hours}\right)^{2/3}$$

Where: Ch = daily rainfall (mm)

$$Q = C \times I \times A$$

Where:
Q = runoff discharge (m^3/hour)
C = runoff coefficient
I = rainfall Intensity (m/hour)
A = catchment area (m^2)

Runoff volume is depended on runoff discharge and the duration of water discharge (Narajan 2012):

$$V = Q \times t$$

Where:
V = runoff volume (m3)
Q = runoff discharge (m^3/hour)
t = time discharge (hour)

Sustainability Analysis of Porous Concrete

Sustainability analysis by using MDS RAPFISH through the R software application version 4.0.3 (2020). The stages of the RAPFISH sustainability analysis on the porous concrete are as follows: (1) identification of sustainability issues to be analyzed based on an ecological, economic, social, and institutional dimension; (2) determination of the unit of analysis and attributes; (3) scoring each attribute based on the sustainability criteria of each dimension through literature review or interviews or field observations; (4) data entry with MS excel-CSV format; (5) run RAPFISH-R; (6) leverage analysis to determine the attributes of levers that affect to sustainability; and (7) analysis of radar diagrams to find out the sustainability index of each dimension. The sustainability index on MDS-RAPFISH is defined by four groups to show the level of sustainability in each dimension (Abdullah et al. 2011). The sustainability index, as follows: 1) 0–25: bad (unsustainable); 2) 26–50: less (less sustainable); 3) 51–75: sufficient (sufficiently sustainable); 4) 76–10: good (very sustainable).

Strategy Analysis of Porous Concrete

The results of the previous analysis to be used as reference of the study using descriptive analysis methods so that the right direction and strategy will be obtained for supporting the sustainability of the use of porous concrete at various construction project. Each attribute (Table 1) from each dimension (ecology, economy, institutional and technical) to be scored with the defined method and the attribute which has sensitive impact to sustainability will be chosen for focused strategy. The sensitive attribute is defined based on RMS value > 2.5 (Abdullah et al. 2011).

Table 1 Sustainability attributes of porous concrete

Ecology dimension	Economy dimension	Institutional dimension	Technical dimension
1. Infiltration rate 2. Water quality control 3. Reduce run-off 4. Flood control 5. Surface temperature control 6. Increase groundwater reserves 7. Supporting green open space (RTH) and sustainable infrastructure 8. Support green basic coefficient (KDH)	1. Total cost ownership/Life cycle cost (LCC) 2. Maintenance cost 3. Installation fee/initial investment 4. Product availability 5. Durability 6. The added value of the economic aspect for consumers 7. Reduce construction costs (no need to build drainage system)	1. Local regulation alignment with RTH and RTRW 2. Procurement system support 3. Rules/policy for the use of porous concrete 4. Spatial planning and development of urban areas in support of water security 5. The role of associations in the application of green concrete 6. Budget support 7. Availability of green concrete standard	1. Cleanliness of the surrounding environment 2. Pavement function/strength 3. Void condition of porous concrete 4. Supports aesthetics 5. Maintenance (post-construction) 6. Design of porous concrete according to field conditions 7. Quality of porous concrete 8. Manufacturer support for maintenance 9. Public perception/understanding

RESULT AND DISCUSSION

Scoring each attribute is based on an expert judgment which refer to literature review, survey, or field observations. The scoring uses the range number from 0 (bad) to 10 (good). Each atributes should have the clear scoring criteria so that the assessor has clear guidance when put the score 1 to 10. For example for five scoring groups: none impact (score 0–2), less impact (score 3–4), neutral (score 5–6), moderate impact (7–8), big impact (9–10).

Ecology Dimension Analysis

Scoring of all attributes in the ecology dimension is based on expert judgment, which refers to surveys, interviews with practitioners, literature review, and calculation. The final scoring can be shown in Table 2. Criteria of each atribute on ecology dimension are defined based on five scoring groups.

Table 2 Scoring of ecology dimension

No	Attribute	GBK	Depok	Mabes AD	Remark
1.	Infiltration rate	6	5	7	Survey and literature (Cheng et al. 2019)
2.	Water quality control	9	9	9	Survey and literature (Cheng et al. 2019)
3.	Reduce runoff	9	9	9	Calculation
4.	Flood control	9	9	9	Survey and literature (Cheng et al. 2019)
5.	Surface temperature control	9	9	9	(Kevern 2011)
6.	Increase groundwater reserves	9	9	9	Cheng et al. 2019)
7.	Support green open space	9	9	9	Survey and interview
8.	Support green basic coefficient	9	9	9	Survey and interview

Run Off Calculation

The type of porous concrete pavement surface can reduce the runoff about 95% when compared to conventional concrete or asphalt pavements (Table 3). GBK project is one of the biggest pavement projects in Indonesia which use the green concrete. Concrete or asphalt pavement has the biggest runoff coefficient (C = 0.95), meanwhile the porous concrete is only 0.05. Unfortunately, this pavement type is very commonly used in various city in Indonesia or other country. The calculation of runoff uses the highest rainfall data in the latest 5 years from BMKG (2017–2022).

Table 3 Run off calculation based on pavement type

Water infiltration	Unit	Gbk	Depok	Army field
Rainfall	m/day (highest rainfall in latest 5 years)	0.38	0.28	0.38
Pavement area (A)	m^2	42,347	2,673	3,550
Percolation rate	lt/minute/m^2 (test result)	318	318	318
Drainage capacity	m^3/minute	13,466	850	1,129
Volume Runoff (V) - m^3	Porous concrete (C = 0.05)	798	50	37
	Concrete/asphalt (C = 0.95)	15,167	944	711
	Grass (C = 0.22)	3,512	219	165
Different runoff (conventional concrete vs porous concrete)		14,368	895	674

Economy Dimension Analysis

Scoring of all attributes in the economic dimension is based on expert judgment, which refers to a survey, interview with a practitioner, literature review, and calculation. Criteria of each atribute on economy dimension are defined based on five scoring groups (Table 4).

Table 4 Scoring of economy dimension

No	Attribute	GBK	Depok	Army field	Remark
1.	Total cost ownership (TCO)	8	8	8	Calculation*
2.	Maintenance cost	8	8	8	lower maintenance (Moretti et al. 2019)
3.	Installation cost	4	4	4	higher installation cost (Moretti et al. 2019)
4.	Product availability	8	8	8	Site survey and interview
5.	Durability	8	8	9	Site survey and interview

No	Attribute	GBK	Depok	Army field	Remark
6.	The added value for a customer	5	5	5	higher installation cost (Moretti et al. 2019)
7.	Reduce construction costs	9	9	9	Calculation*

Installation Cost and TCO Calculation

Initial installation cost of porous concrete is the highest one if compared with the other pavement type. However, if the cost calculation also inluded the facilities for cathing up the runoff volume like the installation with infiltration wells where per unit cost of infiltration wells which have the diameter 98 cm, lenght 300 cm and volume 2.26 m^3 is IDR 6,600,000 or IDR 2,920,400 per m^3, then the total installation cost of porous concrete and the supporting facilities is not much different from the conventional pavement (asphalt or concrete) (Table 5, 6, 7 and 8).

Table 5 Data comparison of pavement installation cost per unit measure

Cost per unit measure	**Infiltration well**	**Asphalt/ concrete**	**Paving block**	**Porous concrete**
Cost (IDR/m3) - installed	2,920,400			
Cost (IDR/m2) - installed		105,000	175,000	700,000
Coefficient run-off (C)		0.95	0.70	0.05

Tabel 6 Calculation of total cost ownership of porous concrete (GBK Senayan)

Simulation Cost-Benefit (GBK Senayan)	**Infiltration well**	**Asphalt/concrete**	**Paving block**	**Porous concrete**
Pavement area GBK – m2 (A)	42,347			
Rainfall- Ch (mm)	200			
whereas V = Ch*Ca*C (m3) → run off		8,046	5,929	423
Cost for infiltration well (IDR)		23,497,333,972	17,313,825,032	1,236,701,788
Installation cost (IDR)		4,446,435,000	7,410,725,000	29,642,900,000
Total Cost Ownership (TCO), excluding maintenance cost (IDR)		27,943,768,972	24,724,550,032	30,879,601,788

Table 7 Calculation of total cost ownership of porous concrete (Mabes TNI)

Simulation Cost-Benefit (Army Field/Mabes TNI)	**Infiltration well**	**Asphalt/concrete**	**Paving block**	**Porous concrete**
Pavement area Army Field (A)	2,673			
Rainfall- Ch (mm)	200			
whereas V = Ch*Ca*C (m3) → run off		507.87	374.22	26.73
Cost for infiltration well (IDR)		1,483,183,548	1,092,872,088	78,062,292
Installation cost (IDR)		280,665,000	467,775,000	1,871,100,000
Total Cost Ownership (TCO), excluding maintenance cost (IDR)		1,763,848,548	1,560,647,088	1,949,162,292

Table 8 Calculation of total cost ownership of porous concrete (Depok)

Simulation Cost-Benefit (Army Field/Mabes TNI)	**Infiltration well**	**Asphalt/concrete**	**Paving block**	**Porous concrete**
Pavement area at Depok (A)	3,550			
Rainfall- Ch (mm)	200			
whereas V = Ch*Ca*C (m3) → run off		674.5	497.0	35.5
Cost for infiltration well (IDR)		1,969,809,800	1,451,438,800	103,674,200
Installation cost (IDR)		372,750,000	621,250,000	2,485,000,000
Total Cost Ownership (TCO), excluding maintenance cost (IDR)		2,342,559,800	2,072,688,800	2,588,674,200

Institutional Dimension Analysis

Scoring of all attributes in the institutional dimension is based on the expert judgment referred to an interview with practitioners, literature, and regulation review. Criteria of each atribute on institutional dimension are defined based on five scoring groups. The final scoring can be shown in Table 9.

Table 9 Scoring of the institutional dimension

No	**Attribute**	**GBK**	**Depok**	**Army field**	**Remark**
1.	Local regulation's alignment with RTH and RTRW	9	2	9	Regulation analysis*
2.	Procurement system support	7	2	7	Regulation analysis*
3.	Rules/ policy for the use of porous concrete	8	5	8	Regulation analysis*
4.	Spatial planning and development of urban areas in support of water security	9	5	9	Regulation analysis*
5.	The role of associations in the application of green concrete	5	5	5	Interview

6.	Budget support	7	3	7	Regulation analysis*
7.	Availability of green concrete standard	2	2	2	Regulation analysis*

Regulation Analysis

The results of the analysis of several regulations related to spatial and building planning are only DKI Regional Regulation number 1/2014 and DKI Governor Regulation number 135/2019 concerning building planning guidelines which have included provisions on pavement that function as a water absorption function in the Green Basic Coefficient (KDH) criteria. Of course, this is very positive in supporting the use of porous concrete in urban areas that have runoff problems, such as in DKI Jakarta. More details can be seen in Table 10.

Table 10 Regulation analysis

No	Applicable regulations	Current status	Support to porous concrete
1.	Law Number 26 year 2007 concerning spatial planning	• Provision and use of green open space/RTH (RTH 30%) → RTH for public (20%)	Not supported yet
2.	Government Regulation number 16 year 2021 regarding buildings	• Use of environmentally friendly materials eco-label certified • Green supply chain (green procurement) • BGH certification: eco-friendly material • site management: providing pedestrian paths (not yet mentioning pavement with water catchment functions)	Not supported yet
3.	Government Regulation number 21 year 2021 regarding the implementation of spatial planning	• RTRW includes: urban green open space • Provision and use of public green space (20%) and private (10%)	Not supported yet
4.	PUPR Ministerial Regulation number 02 year 2015 concerning green buildings (BGH)	• Use of green materials with eco-label certified • Site management: providing pedestrian paths for parking lots (but not yet mentioning pavement with water catchment functions)	Not supported yet
5.	Presidential Regulation number 12 year 2021 concerning the procurement of government goods and services	• There are no statements regarding green materials or pavements with water absorption functions.	Not supported yet
6.	Regulation of the Minister of Public Works number 5 year 2008 concerning guidelines for the provision and utilization of green open space in urban areas	• RTH as a water catchment area, rainwater absorber, and aesthetic function • Non-pavement area: KDH 70-80% (but not yet mentioning pavement with water catchment functions)	Not supported yet
7.	DKI Governor Regulation number 135 year 2019 concerning building planning guidelines	• Pavement that functions as a water absorption function has been calculated as KDH criteria – including: running track, poolside pavement, pedestrian path, bicycle	Yes, supported

No	Applicable regulations	Current status	Support to porous concrete
		path, and parking infrastructure.	
8.	Depok City Perda number 3 year 2018, and Regional Regulation number 1 year 2015 concerning the Depok RTRW	• There is no provision on pavement that functions as water absorption into the KDH criteria.	Not supported yet

Technical Dimension Analysis

Scoring of all attributes in the technical dimension is based on expert judgment, which refers to survey, interview with practitioner, and site observation. Criteria of each atribute on technical dimension are defined based on five scoring groups. The final scoring can be shown in Table 11.

Table 11 Scoring of technical dimension

No	Attribute	GBK	Depok	Army field	Remark
1.	Cleanliness of the surrounding environment	8	6	10	Site observation
2.	Pavement function/strength	9	9	9	Site observation
3.	Void condition of porous concrete	7	6	9	Site observation
4.	Supports aesthetics	8	8	8	Site observation
5.	Maintenance (post-construction)	4	4	8	Site observation
6.	Design of porous concrete	9	7	9	Site observation
7.	Quality of porous concrete	8	6	9	Site observation
8.	Manufacturer support for maintenance	2	2	2	Site observation
9.	Public perception/understanding	4	4	4	Site observation

Sustainability Analysis of Porous Concrete

Based on the scoring of all attributes in each dimension, then run the Rapfish R for MDS analysis. The results of the sustainability analysis using MDS obtained that the sustainability status of porous concrete is in the range of 71.9 (quite sustainable), with the lowest value on the institutional dimension (58.90) (Figure 2 and Table 12). Its align with the regulation analysis (Table 10) that all existing regulation, both national and local, have not supported the implementation of porous concrete except for DKI Governor Regulation number 135 Year 2019 concerning building planning guidelines, where pavement that functions as a water absorption function has been calculated as KDH criteria.

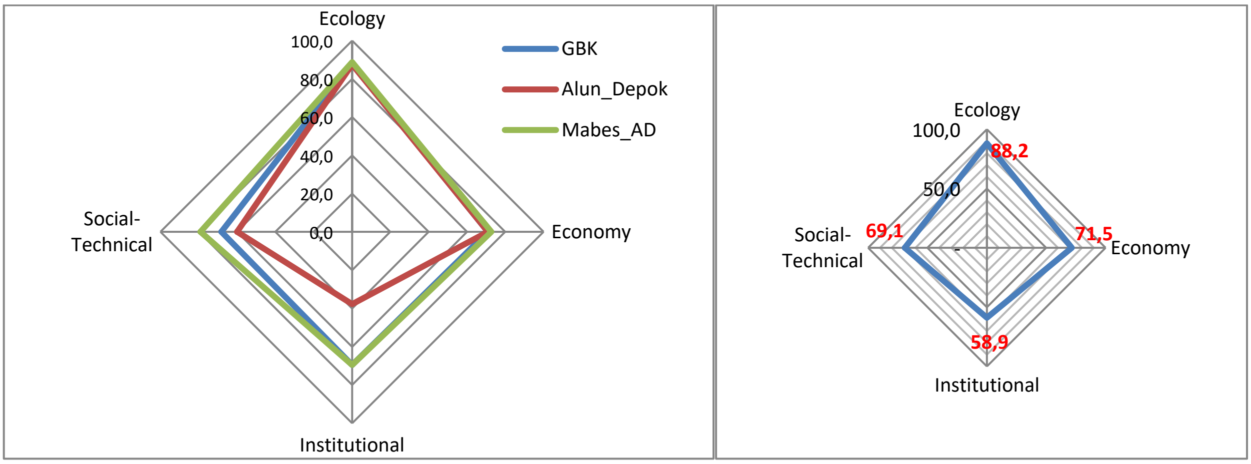

Figure 2 Sustainability status of porous concrete

Table 12 Sustainability status of porous concrete

Project location	**Sustainability status**			
	Ecology	**Economy**	**Institutional**	**Social-technical**
GBK	88.20	70.90	69.50	68.20
Depok	87.50	70.90	37.70	60.00
Army Field	88.80	72.70	69.50	79.10

The sensitive attribute is defined based on RMS value > 2.5, which means the attribute can leverage sustainability or need policy intervention to ensure sustainability. Leverages that affect the sustainability of porous concrete and need policy intervention (Figure 3), including:

1. Ecological dimension: no dominant lever due to all attributes having RMS value < 2.5. It means no need for policy intervention for the sustainability of porous concrete in the ecology dimension.
2. Economic dimensions: identified three sensitive attributes, i.e., consumer added value, durability, installation costs
3. Institutional dimensions: identified five sensitive attributes, i.e., standard application of porous concrete, the role of associations, planning that supports water resistance, policies on the use of environmentally friendly materials, local regulation of RTH/RTRW
4. Socio-technical dimensions: identified six sensitive attributes, i.e., community understanding, manufacturer support, poor concrete design, maintenance, aesthetic function, and pavement function.

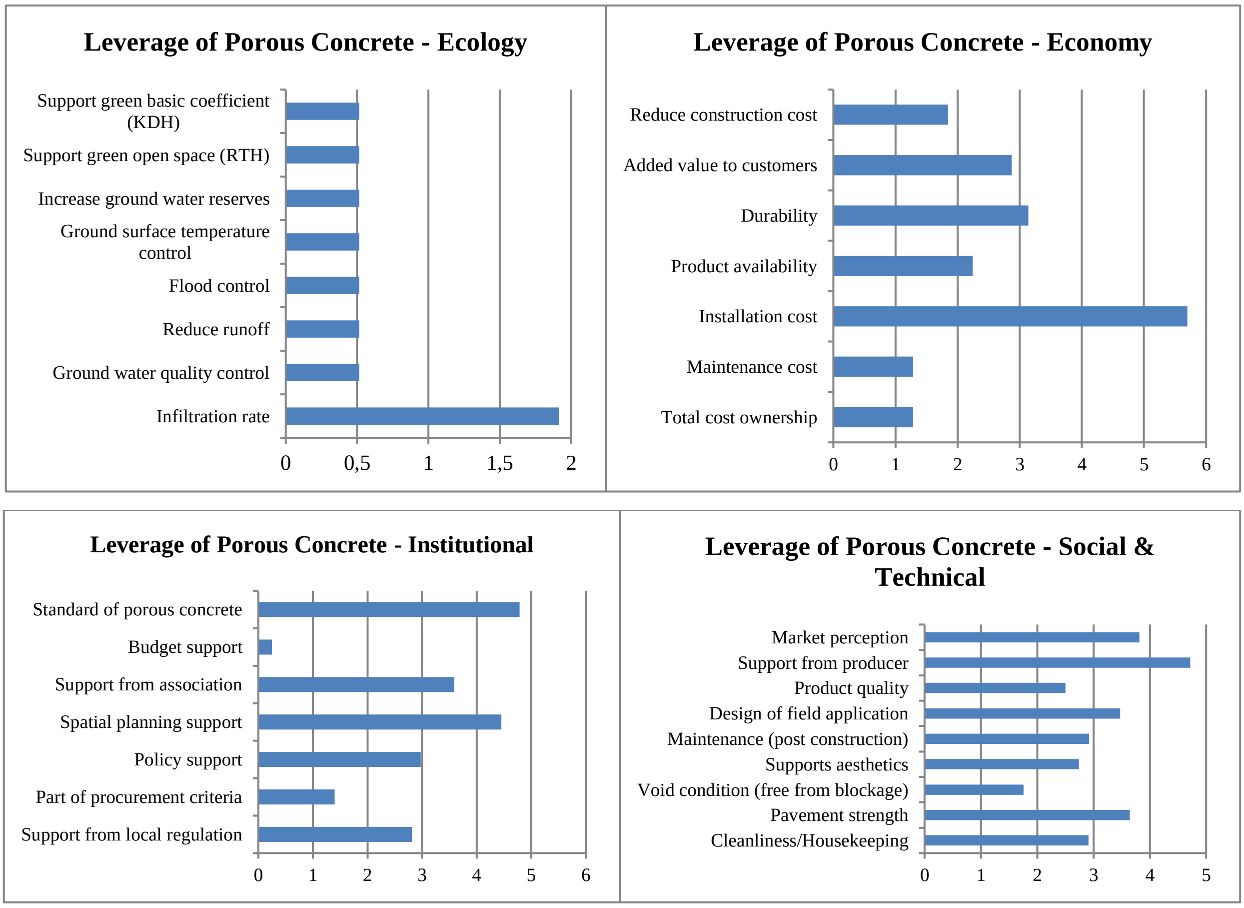

Figure 3 Leverage of porous concrete

Sustainability Strategy of Porous Concrete

Intervention policy is defined based on leverage analysis for ensuring the sustainability of porous concrete implementation. The alternative strategies are defined based on expert judgment, which refers to experience, literature study, survey, interview with practitioner, and site observation the recommendation of an alternative strategy for each sensitive leverage can be shown in Table 13.

Table 13 Alternative of sustainability strategy

Leverage	Alternative strategy for sustainability	Stakeholders
Customer added value	Incorporating porous concrete as a KDH criterion and the ease of obtaining building approvals	Local goverment (PUPR), Verifikation Body of BGH
Durability	▪ Develop the standard product for the manufacture and maintenance of porous concrete ▪ Supervision of implementation in the field	Concrete Asociation, PUPR, BSN
Installation costs	▪ Total cost ownership (TCO) calculation ▪ Technology sharing	Bappeda, Local goverment (PUPR), concrete producer, Asociation
Standard application of porous concrete	▪ Develop standards for the manufacture, installation and maintenance of pore concrete ▪ Supervision of implementation in the field	Academic, Concrete Asociation, PUPR, BSN
The role of associations	▪ Outreach to manufacturers, contractors and consultants to encourage the application of porous concrete	Concrete Asociation, producer, contractor and consultant
Planning that supports water resistance Policies on the use of environmentally friendly materials Local regulation of RTH/RTRW	▪ Incorporating porous concrete as a standard pavement for green open spaces/city parks, pedestrians/sidewalks, parking lots, office buildings and shopping centers, parks in school/campus environments, housing complexes, and other open public spaces	PUPR, Bappeda, Local goverment (PUPR)
Community understanding	Dissemination to related parties: academics, contractors, and consultants to encourage the application of porous concrete	Academics, contractors, consultants, Architect Association
Manufacturer Support	▪ Proper construction design ▪ Consulting services and post-installation maintenance services so that the water catchment function continues to function properly ▪ Reducing the price of products and services	Concrete producer
Porous concrete design and maintenance	▪ Develop standards for the installation and maintenance of porous concrete ▪ Supervision of applications in the site project	Concrete producer, contractor, and consultant

CONCLUSION

Generally, the sustainability status of green concrete or porous concrete application is 71.9, which is categorized as quite sustainable. Based on the analysis of leverage, several things need to be the focus of policy-making, such as: (1) higher installation price is still an obstacle to implementation of porous concrete; (2) lack of design affects the sustainability of the water absorption function of porous concrete; (3)

misunderstanding and wrong perception of customer is still an obstacle; (4) porous concrete pavement is more effective in reducing rainwater runoff so that if used widely it can be a flood control solution in urban cities; (5) local regulations (RTH/KDH) still do not support the implementation of porous concrete.

REFERENCES

[Perda Kota Depok] Peraturan Daerah Kota Depok. 2018. Peraturan Kota Depok nomor 3 tahun 2018 tentang Penyelenggaraan Kota Hijau. Depok: Pemerintah Daerah Kota Depok.

[Perda Provinsi DKI Jakarta] Peraturan Daerah. 2014. Peraturan Daerah Provinsi DKI Jakarta Nomor 1 Tahun 2014 tentang Rencana Detail Tata Ruang Dan Peraturan Zonasi. Jakarta: Pemerintah Provinsi DKI Jakarta.

[Perda Provinsi DKI Jakarta] Peraturan Daerah. 2021. Peraturan Daerah DKI Jakarta nomor 21 tahun 2021 tentang Rencana Tata Ruang. Jakarta: Pemerintah Provinsi DKI Jakarta.

[Pergub DKI Jakarta] Peraturan Gubernur. 2019. Peraturan Gubernur DKI Jakarta Nomor 135 Tahun 2019 Panduan Perencanaan Bangunan, Jakarta: Pemerintah Provinsi DKI Jakarta.

[Pergub DKI Jakarta] Peraturan Gubernur. 2021. Peraturan Gubernur DKI Jakarta Nomor 16 Tahun 2021 Tentang Bangunan. Jakarta: Pemerintah Provinsi DKI Jakarta.

[PRI] Pemerintah Republik Indonesia. 2007. Undang-Undang Nomor 26 Tahun 2007 Tentang Rencana Tata Ruang, Indonesia. Jakarta: Sekretariat Negara RI.

[PRI] Pemerintah Republik Indonesia. 2021. Peratura Presiden Nomor 12 Tahun 2021 Tentang Pengadaan Barang dan Jasa di Pemerintahan. Jakarta: Sekretariat Negara RI.

[PUPR] Pekerjaan Umum dan Perumahan Rakyat. 2015. Peraturan Menteri Pekerjaan Umum dan Perumahan Rakyat Nomor 02 Tahun 2015 Tentang Bangunan Ramah Lingkungan. Jakarta: Kementerian PUPR Republik Indonesia.

[PUPR] Pekerjaan Umum dan Perumahan Rakyat. 2008. Peraturan Menteri Pekerjaan Umum dan Perumahan Rakyat Nomor 5 Tahun 2008 Tentang Panduan untuk Penyediaan dan Pemanfaatan Ruang Terbuka Hijau di Kawasan Perkotaan. Jakarta: Kementerian PUPR Republik Indonesia.

Abdullah RM, Wisudo SH, Monintja DR, Sondita MFA. 2011. Keberlanjutan perikanan tangkap di Kota Ternate pada dimensi ekologi. *Buletin PSP*. 19(1):113–126.

Cheng YY, Lo SL, Ho CC, Lin JY, Yu SL. 2019. Field testing of porous pavement performance on runo and temperature control in Taipei City. Water. 11(2635):1–15.

Elizondo-Martínez EJ, Andres-Valeri VC, Jato-Espino D, Rodriguez-Hernandez J. 2019. Review of porous concrete as multifunctional and sustainable pavement. *Journal of Building Engineering*. 27(100967):1–9.

Fauzi A, Anna S. 2002. Evaluasi status keberlanjutan pembangunan perikanan: aplikasi pendekatan RAPFISH. *Jurnal Pesisir dan Lautan*. 4(3):43–55.

Harbowoputri S. 2018. Kajian pengaruh penggunaan perkerasan terhadap fungsi hidrologis taman kota di Kota Bekasi [undergraduate thesis]. Bogor: IPB University.

Hardiani N. 2016. Hardiani N. 2016. Faktor-Faktor yang mempengaruhi penerapan *green procurement* dalam proses pengadaan material konstruksi di Indonesia [thesis]. Surabaya: Institut Teknologi Sepuluh Nopember.

Kevern J. 2011. *Louisiana Transportation Conference, Baton Rouge*. Columbia (DC): University of Missouri.

Moretti L, Di Mascio P, Fusco C. 2019. Porous concrete for pedestrian pavements. Water. 11(2105):1–13. doi:10.3390/w11102105.

Narajan D. 2012. Development of guidance for runoff coefficient selection and modified rational unit hydrograph method for hydrologic design [dissertation]. Alabama (AL): Auburn University.