Supplementary Materials

Evaluation of engineering properties of powdered activated carbon amendments in porous asphalt pavement

Contents

Table S1. Summary of the BTEX concentrations in ambient air.

Country	City or sampling site	Concentration (μg/m^3)					Sampling period	Reference
		B	T	E	X	Total		
Taiwan	Nei-Pu	6.72	8.86	1.87	13.75	31.20	2003/07-2004/12	(Hsieh et al., 2006)
	Ping-Tung	5.86	9.70	7.79	17.18	40.53		
	Ping-Nan	6.54	16.90	6.24	16.71	46.39		
	Ren-Wu	6.57	56.63	10.95	32.10	106.25		
	Lin-Yuan	25.84	23.47	8.44	27.68	85.43		
	Nan-Zi	7.16	21.09	5.86	22.26	56.37		
Japan	Ashiya	1.6	13	8.1	8.7	31.4	2005-2009	(Okada et al., 2012)
	Sumoto	2	12	8.1	8.7	30.8		
Korea	Yangsan	0.67	5.09	4.39	7.6	17.75	2006/02-2006/12	(Song et al., 2009)
Spain	Pamplona	2.84	13.26	2.15	6.01	24.26	2006/06-2007/06	(Parra et al., 2009)
India	Delhi	48	85	7	45	185	2001/10-2002/09	(Hoque et al., 2008)
USA	Camden	1.35	2.48	0.40	1.68	5.91	2004/06-2006-07	(Fan et al., 2012)
El Paso	Near-road (indoor air)	1.68	17.06	2.11	3.72	24.57	2010 Spring	(Raysoni et al., 2017)
	Near-road (outdoor air)	2.41	8.21	1.55	5.9	18.07		

Table S2. Summary of the BTEX concentrations in rainwater.

City	Sampling period	Concentration (μg/L)				Reference
		B	T	E	X	
Wilmington, USA	2012/8-2012/8	0.023	0.071	0.037	0.025	(Mullaugh et al., 2015)
Hino, Japan	2004/7-2005/1	0.002	0.305	-	0.244	(Sato et al., 2010)
Yokohama, Japan	1999-2000	0.154	0.347	-	0.072	(Okochi et al., 2004)

Table S3. The test methods and equations for PAP physical performance.

Test item	Formulation		Reference
Marshall method of mix design	-	-	AASHTO T245
Marshall stability	-	-	ASTM D6927-06
Marshall flow	-	-	
Dynamic stability	$DS = 630/(d_{60}-d_{45})$	DS: dynamic stability (passes/mm) d_{60}: rut depth after 60 minutes (mm) d_{45}: rut depth after 45 minutes (mm) DR: deformation rate (mm min^{-1})	ASSHTO T324
Deformation rate	$DR = (d_{60}-d_{45})/15$		
Retained strength	$RS = S'/S\times100\%$	RS: retained strength (%) S': the specimen strength after moisture damage (kgf) S: initial strength of the specimen (kgf)	AASHTO T283 ASTM D1074
Abrasion	$Ab = (E-F)/E\times100\%$	Ab: abrasion loss (%) E: the initial weight (g) F: the retained weight (g)	ASTM D7064
Draindown	$Dd = (D-C)/(B-A)\times100\%$	Dd: draindown loss (%) A: the wire basket weight (g) B: the sample weight plus wire basket (g) C: the tray weight (g) D: the tray weight after an hour in the oven (g)	AASHTO T305
Void	$V_A = D_{GA}/D_{mm}\times100\%$	V_A: Void (%) D_{GA}: apparent specific gravity (g cm^{-3}) D_{mm}: maximum specific gravity of mixture (g cm^{-3})	ASTM D3203
Permeability	$k = \rho\times(\alpha L/At)\times\ln(h_0/h)$	k: coefficient of permeability (cm s^{-1}) ρ: the corrective coefficient for test temperature other than 20 °C α: area of pipe (cm^2) L: length of specimen (cm) A: area of specimen (cm^2) t: elapsed time of test (s) h_0: head of beginning of test (cm) h: head at end of test (cm)	ASTM D3637
DS_w	$DS_w = 630/(dw_{60}-dw_{45})$	DS_w: Wet dynamic stability (passes mm^{-1}) dw_{60}: rut depth in 60 °C water after 60 minutes (mm) dw_{45}: rut depth in 60 °C water after 45 minutes (mm) RD_w : Wet deformation rate (mm min^{-1})	ASSHTO T324
DR_w	$RD_w = (dw_{60}-dw_{45})/15$		
Cont. porosity	$V_C = \{[V-(W_A-W_W)]/V\}\times100\%$	V_C : continuous porosity (%) V: specimen volume (cm^3) W_A: dry specimen weight (g) W_W: specimen weight in water (g)	MOTC road engineering construction criteria
Closed porosity	$V_D = V_A-V_C$	V_D: Closed porosity (%) V_A: Voids of the specimen (%) V_C: continuous porosity (%)	
ITS	$ITS = 2T/\pi td$	ITS: indirect tensile strength (kgf cm^{-2}) T: the failure load (kgf) t: sample thickness (cm) d: sample diameter (cm)	ASTM D6931
VMA	$VMA = \{1-[G_{mb}\times(1-P_b)/G_{sb}]\}\times100\%$	VMA: voids in mineral aggregate (%) G_{mb}: bulk specific gravity of compacted mixture (g cm^{-3}) P_b: asphalt content, percent by weight of aggregate (%) G_{sb} bulk specific gravity of aggregate VFA: voids filled with asphalt (%) VTA: air voids in compacted mixture (%)	AI MS-4
VFA	$VFA = [(VMA-VTA)/VMA]\times100\%$		

Reference: Chinese National Standards (CNS) (http://www.cnsonline.com.tw/); American Society for Testing and Materials (ASTM) (https://www.astm.org/); American Association of State Highway and Transportation Officials (AASHTO) (http://www.transportation.org/); Asphalt Institute (AI) (http://www.asphaltinstitute.org/); Ministry of Transportation and Communications (MOTC) road engineering construction criteria (http://www.motc.gov.tw/)

Table S4. The properties of coarse aggregates.

Item	Specification	Test value	Test method
Los Angeles abrasion (500 cycles, %)	30 (max.)	14.2	CNS 490 A3009
Flat & Elongated (%)			
3:1	12 (max.)	4.8	CNS 15171 A3408
5:1	5 (max.)	1.2	
Water adsorption (%)	2 (max.)	0.92	CNS 488 A3007
Saturated surface dry	2.45 (min.)	2.63	
Soundness (Sodium sulfate, 5 cycles, %)	12 (max.)	0.68	CNS 1167 A3031
Crushed content (%)			
>One face	100 (min.)	100	ASTM D5821
>Two faces	90 (min.)	98	

Reference: Chinese National Standards (CNS) (http://www.cnsonline.com.tw/);
American Society for Testing and Materials (ASTM) (https://www.astm.org/)

Table S5. The properties of fine aggregates.

Item	Specification	Test value	Test method
Soundness (Sodium sulfate, 5 cycles, %)	15 (max.)	1.22	CNS 1167 A3031
Liquid limit (%)	25 (max.)	0	CNS 5087
Plastic index (%)	Nonplastic	Nonplastic	CNS 5088
Sand equivalent (%)	45 (min.)	76	AASHTO T176

Reference: Chinese National Standards (CNS) (http://www.cnsonline.com.tw/); American Society for Testing and Materials (ASTM) (https://www.astm.org/); American Association of State Highway and Transportation Officials (AASHTO) (http://www.transportation.org/)

Table S6. The properties of modified asphalt.

Item	Specification	Test value	Test method
Penetration (25 ºC, 100 g, 5 sec, 0.1 mm)	35 (min.)	48	CNS 10090 K6755
Soften point (ºC)	80 (min.)	95.2	CNS 2486
Ductility (15 ºC, 1 cm)	-	92.1	CNS 10091
Flash point (ºC)	232 (min.)	352	CNS 3775 K6377
Rate of mass loss (%)	-	0.0122	ASSHTO T179-05
Residual rate of penetration (%)	-	99.88	
Viscosity (Poise) @ 60 ºC	8000 (min.)	23200	CNS 14186
Solubility in TCE (%)	99 (min.)	99.98	CNS 10092 K6757
Segregation (ºC)	-	0.6	CNS 14184 K5150
RTFO elastic recovery (%)	70 (min.)	80.2	CNS 14184 K5150
RTFO penetration (4 ºC, 200 g, 60 sec)	10 (min.)	28.5	CNS 14184

-: No specification in MOTC; RTFO: Rolling Thin Film Oven

Reference: Chinese National Standards (CNS) (http://www.cnsonline.com.tw/); American Society for Testing and Materials (ASTM) (https://www.astm.org/); American Association of State Highway and Transportation Officials (AASHTO) (http://www.transportation.org/)

Table S7. Grading specification and the gradation for PAP and PRP-PACs.

Sieve size	Percent passing by weight (%)					
	Upper limitation	Lower limitation	PAP	PRP-PAC04	PRP-PAC08	PRP-PAC15
1 in	100	100	100	100	100	100
3/4 in	100	95	96	96	96	96.1
1/2 in	84	64	67	67.1	67.3	67.5
3/8 in	-	-	49	49.2	49.4	49.8
No. 4	31	10	13	13.3	13.7	14.3
No. 8	20	10	11	11.4	11.7	12.3
No. 16	-	-	10.4	10.8	11.1	11.7
No. 30	-	-	9.8	10.2	10.5	11.2
No. 50	-	-	8.4	8.8	9.1	9.8
No. 100	-	-	7	7.4	7.7	8.4
No. 200	7	3	5.6	6	6.4	7

Note: Aggregates for sieve size 3/8 in, and sieve number between 16 and 100 are not regulated; however the designed gradation curve must be within the upper and lower limit gradation curves, in accordance with the MOTC specification.

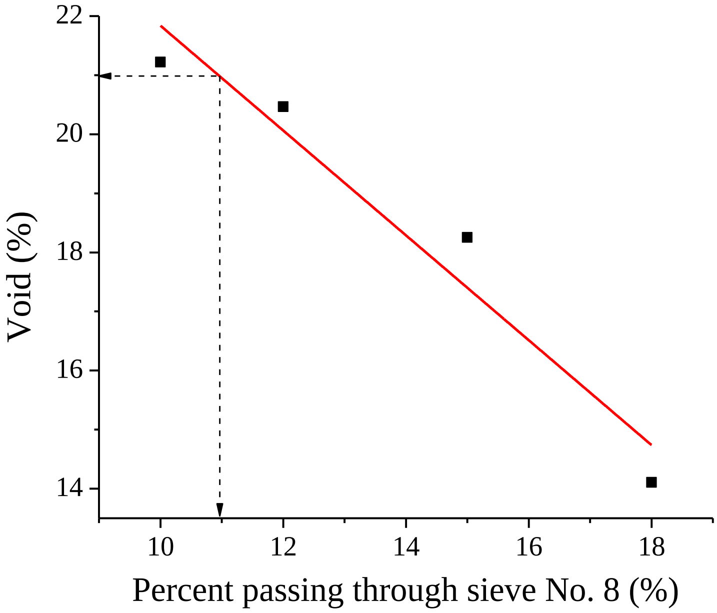

Figure S1. Various compositions of aggregates passing through sieve No. 8 used for determining voids of PAP and PRP-PACs.

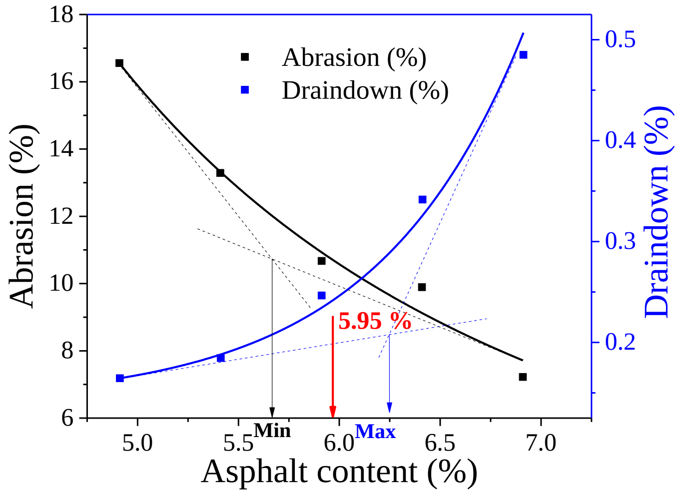

Figure S2. Determination of optimum asphalt content dependent upon abrasion and drain-down tests.

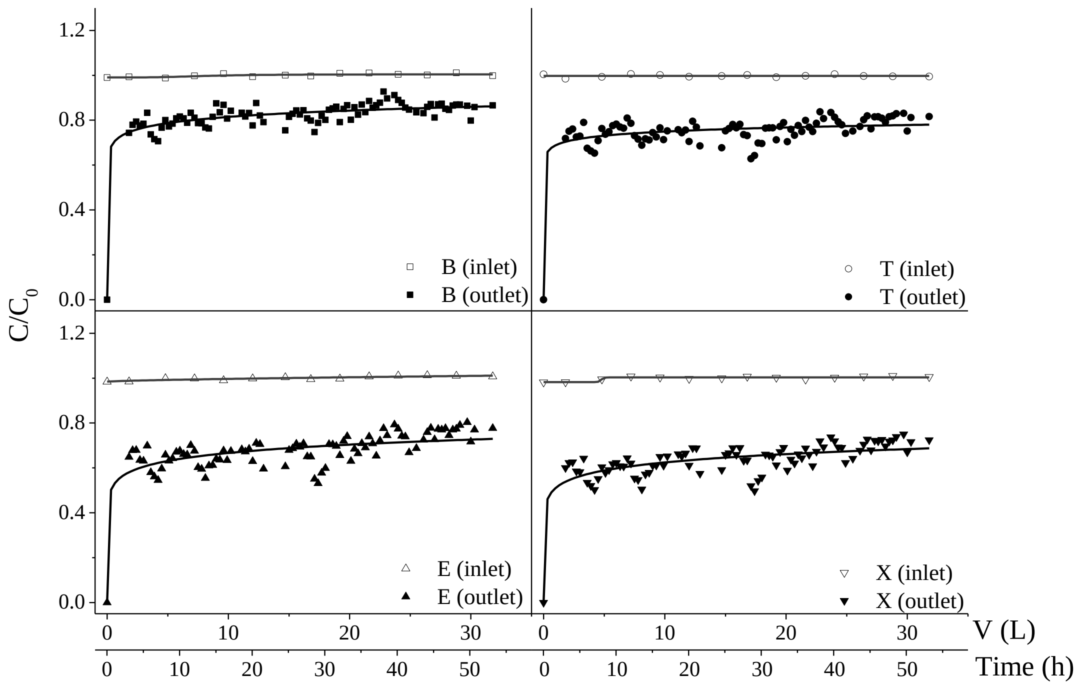

Figure S3. The breakthrough curves of BTEX sorption onto PAP.

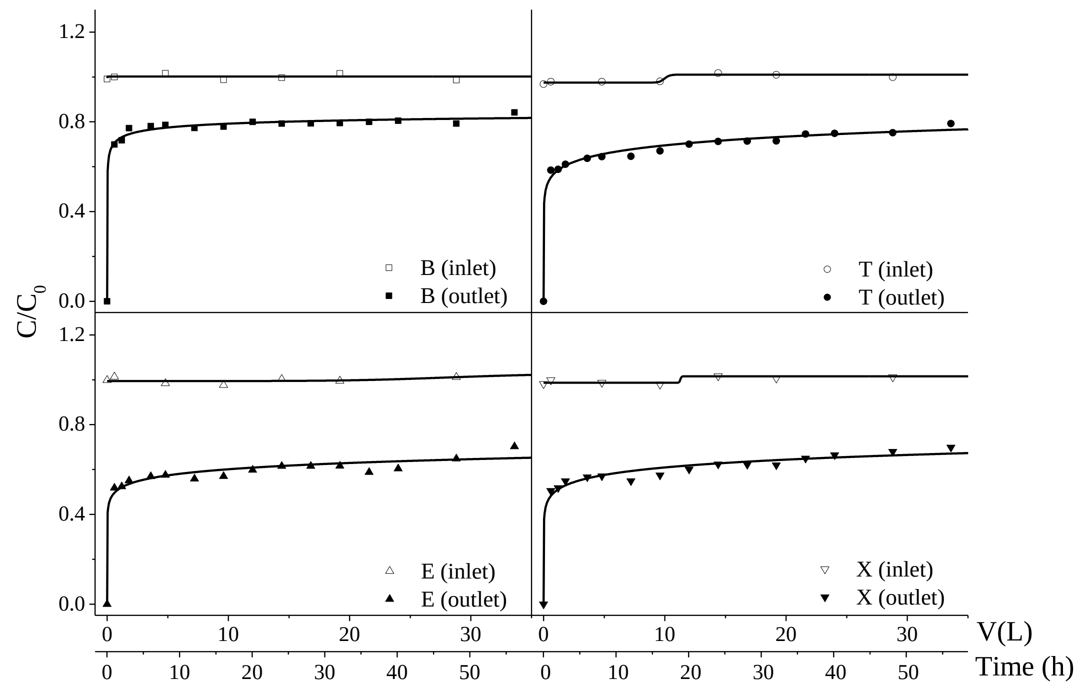

Figure S4. The breakthrough curves of BTEX sorption onto PRP-PAC08.

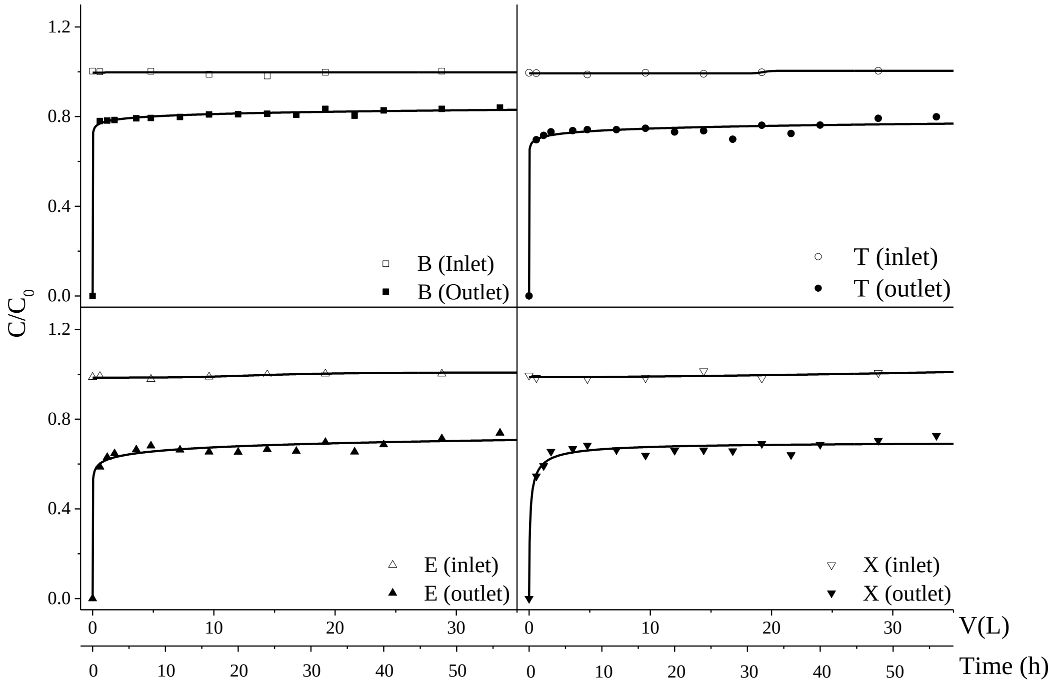

Figure S5. The breakthrough curves of BTEX sorption onto PRP-PAC15.