Kor. Turfgrass Sci., 20(1), 83~91, 2006

Effect of Rootzone Mixes Amended with Crumb Rubber on the Physical Properties

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폐 타이어 고무칩을 혼합한 개량제의 물리성 개선 효과

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ABSTRACT

This research was initiated to enhance the tilth of fine-textured soil for turf growth by incorporation of crumb rubber shredded from used tires. A specific objective was to determine the physical properties of soil mixes amended with different grade and amount of crumb rubber in soils.

Two soils and three different grades(3.5, 6.5 and 9.5 mm) of crumb rubber were used. The soils selected were an Arenzville silt loam(coarse-silty, mixed, nonacid, mesic Typic Udifluvents) and a Hosmer silty clay loam(fine-silty, mixed, mesic Typic Fragiudalfs). The amount of crumb rubber mixed in soil ranged from 0 to 0.4 $g \cdot g^{-1}$(using 0.05 $g \cdot g^{-1}$) increments and 0 as a control. For each treatment, soil cores were constructed following the recommendation by the United States Golf Association Green Section Record.

Results indicated that porosity of the mixes decreased as the amount of crumb rubber increased. Regardless of the grade of crumb rubber, mixes with less than 0.15 $g \cdot g^{-1}$ of crumb rubber in fine-textured soil could not enhance their macro-porosity and hydraulic conductivity. However, as the amendment increased over 0.15 $g \cdot g^{-1}$, the tilth of the mixes had improved significantly macro-porosity, hydraulic conductivity and air permeability, as compared with a control.

Key words : amendment, crumb rubber, rootzone mixes, soil physical properties, turfgrass

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INTRODUCTION

Incorporation of shredded rubber into sports turf is a newly developing idea(Logsdon, 1990; Malmgren et al., 1991; Riggle 1994; Rogers et al., 1994; Groenevelt and Grunthal, 1998). It is believed that crumb rubber will enhance soil physical properties and improve surface resiliency(Logsdon, 1990; Rogers et al., 1998). Hence it will strengthen turfgrass playing performance and reduce sport injury. However, most of the studies on crumb rubber as an amendment to enhance the tilth of the rootzone medium for turf growth have worked on soils with medium to coarse particle sizes(Rogers et al., 1994).

The aim of this study was to incorporate shredded tires as an amendment into indigenous fine-textured soil to enhance its tilth. The specific objectives of this study were to determine the optimal grade and amount of crumb rubber for the construction of optimal rootzone mixes for turf growth in sports fields.

METHODS AND MATERIALS

Two different soils were used in this study. The soils were Arenzville silt loam(coarse-silty, mixed, nonacid, mesic Typic Udifluvents; Goddard and Sabata, 1986) and Hosmer silty clay loam(fine-silty, mixed, mesic Typic Fragiudalfs; Herman et al., 1979). The Arenzville silt loam was sampled from a soccer field located on the west side of the soccer stadium at the Southern Illinois University Edwardsville(SIUE) campus. The composite soil sample was collected from 0 to 150 mm at six different locations selected randomly within the soccer field. The Hosmer silty clay loam was obtained from a newly established turf experimental field at the Horticulture Research Center(HRC), Southern Illinois University Carbondale(SIUC) campus.

Prior to the test, the samples were air-dried and sieved through a 2 mm sieve. The textural properties of these two soils were analyzed by the hydrometer method(Gee and Bauder, 1986). Before mixing with crumb rubber, the moisture-density curve(Das, 1989) of each soil was developed to obtain the optimum moisture content for compaction. In the experiment, three different grades(average 3.5, 6.5 and 9.5 mm) of crumb rubber were tested. The amendment rates(treatments) ranged from 0(as a control) to 0.4 g · g^{-1}(at 0.05 g · g^{-1} increments). For each treatment, three soil cores(100 mm long with a diameter of 79 mm) were constructed following the recommendation by the USGA Green Section Record(1993). Soil cores were saturated by capillary action for 48 h prior to measuring hydraulic conductivity, K_{sat}. The measurement of K_{sat}, was conducted using constant head approach(Klute and Dirksen, 1986). Water retention characteristics of the soil cores were obtained by the hanging water column technique(Klute, 1986) at -1, -3, -5, -15 and -20 kPa. After the water retention experiment was completed, air permeability, K_{air} of the core(at -20 kPa) was measured by a gasometer(Corey, 1986). The core was oven-dried at 105°C for calculating porosity.

Porosity, P, of a soil core is often calculated by

$$P = 1 - (D_b / D_{pm}) \qquad \text{Eq. [1]}$$

where D_b is the bulk density of the core, and D_{pm} is the particle density of the soil mineral(assumed to be 2.65 Mg m^{-3}). However, due to the difference in particle density between soil mineral and crumb rubber, porosity of the mixes was calculated according to the method of Chong et al.(1998):

$$P = 1 - [(D_b / D_{pm})(1 - k) + D_b(k / D_{cr})] \qquad \text{Eq. [2]}$$

where D_b is the bulk density of the core, D_{cr} is particle density of crumb rubber, and k is the fraction($g \cdot g^{-1}$) of crumb rubber in the mix. Both particle densities of soil mineral and crumb rubber were determined by the pycnometer method(Blake and Hartge, 1986).

RESULTS AND DISCUSSION

The particle densities of the Arenzville silt loam, Hosmer silty clay loam and crumb rubber were found to be 2.67, 2.78 and 1.2 Mg m^{-3}, respectively. The results of textural analysis are presented in Table 1. Even though results indicated that Hosmer silty clay loam had a slightly higher sand separate content, its clay content was 10% higher compared with the Arenzville silt loam. However, both soils had the same amount of organic matter content of about 1.2%. The organic content in soils was not considered in the porosity calculation mainly because of the uncertainty of organic form existing in samples.

Table 1. Textural analysis of the Arenzville silt loam and Hosmer silty clay loam

Soil Name	Sand	Silt	Clay
		%(w/w)	
Arenzville silt loam	9.4	71.8	18.8
Hosmer silty clay loam	11.3	59.7	29

Soil-Moisture-Density Curves

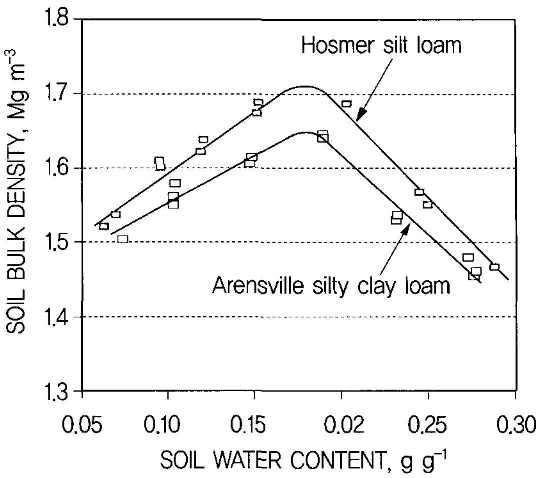

Fig. 1. Soil-moisture-density curves of the Arenzville silt loam and Hosmer silty clay loam.

The soil-moisture-density curves of the Arenzville silt loam and Hosmer silty clay loam are shown in Figure 1. Results indicated that both soils had an optimum compaction moisture content close to 0.18 g · g^{-1}. In order to provide a manageable condition in the laboratory, the water content of both soils was controlled within 95% of the maximum density value prior to the manufacture of soil cores. For the 95% of maximum density, moisture content of the soils ranged from about 0.13 to 0.21 g · g^{-1}. For this study, the moisture was controlled at 0.17 g · g^{-1}. Results in Figure 1 also showed that the Hosmer silty clay loam(fine-textured soil) was more vulnerable to compaction than the Arenzville silt loam(coarse-textured soil).

Porosity

Table 2 shows the mean porosity of both soils amended with various amounts of crumb rubber of the three grades, calculated from Eq. [2]. Results showed that porosity decreased as the amount of crumb rubber amended in soil increased regardless of the grade difference in crumb rubber. It is important to note that the grades of the crumb rubber selected in this study were larger than sand particles(USDA defines sand with a particle size between 0.05 to 2 mm). Theoretically,

Table 2. Comparison of mean total porosity(%, v/v) of rootzone mixes amended with crumb rubber.

Amount of Amendment (g · g^{-1})	Crumb rubber grade					
	Arenzville silt loam			Hosmer silty clay loam		
	3.5 mm	*6.5 mm*	*9.5 mm*	*3.5 mm*	*6.5 mm*	*9.5 mm*
0.00	45.4 0.72)[z]	45.4(0.72)	45.4(0.72)	49.7(0.29)	49.7(0.29)	49.7(0.29)
0.10	44.3(1.41)	44.4(0.53)	43.8(1.38)	46.1(0.58)	45.4(1.58)	45.4(0.51)
0.15	41.8(0.48)	42.1(0.06)	41.8(2.74)	44.8(1.31)	44.4(1.07)	44.1(0.85)
0.20	39.6(1.86)	40.1(2.40)	41.5(0.42)	44.7(3.39)	42.6(0.52)	42.1(0.45)
0.25	37.8(1.44)	38.4(1.45)	40.1(0.46)	42.2(0.80)	40.8(0.31)	40.9(2.45)
0.30	38.1(3.37)	37.9(6.25)	36.9(1.73)	41.6(1.78)	40.4(1.72)	40.1(2.94)
0.35	37.1(1.68)	34.2(5.37)	36.3(0.50)	42.2(3.00)	37.6(1.26)	38.2(2.36)
0.40	36.1(2.01)	33.2(8.86)	35.6(3.82)	40.8(2.46)	40.3(2.28)	38.5(3.66)

[z] Value in the parenthesis is coefficient of variation.

coarse-textured

soils tend to be less porous than fine-textured soils(Hillel, 1982; Brady and Weil, 1999). In other words, when the amount of coarse particle increases, the pore size of the sample may increase but the porosity of the mixture decreases. The porosities calculated from Eq. [2] matched well with the theory. In addition, the coefficient of variation indicated that, in general, larger variation in porosity was found in soil mix amended with higher amount of crumb rubber.

Macroporosity at -5 kPa

Macro-porosity is defined by the air-filled porosity, P_{mac}, at -4 kPa of water potential(pore size $\geq$75 ㎛)(SSSA, 1996). Since the differences in the P_{mac} values at -4 kPa and -5 kPa were less than 0.02 m^3m^{-3}, the P_{mac} values measured at -5 kPa were used for comparison in order to avoid further interpolation from the moisture characteristic curve. Figures 2(a) and(b) are the results of macroporosity of the mixes. Results indicated that macro-porosity increased as the amount of crumb rubber increased in the mixes. For the mix of the Hosmer silty clay loam, results indicated that adding 0.1 g · g^{-1} of crumb rubber into a fine-textured soil did not enhance the macro-porosity of the mix. On the contrary, it may reach its threshold proportion(Spomer, 1977), and have reduced macro-pores of the rootzone material. However, macro-porosity increased rapidly as the amendment rate increased to 0.2 g · g^{-1} regardless of the grade of crumb rubber. Macro-porosity almost doubled when crumb rubber in the mix increased to 0.25 g · g^{-1} regardless of the grade. Even though a high quantity of crumb rubber added to soil can reduce total porosity of the mix, it

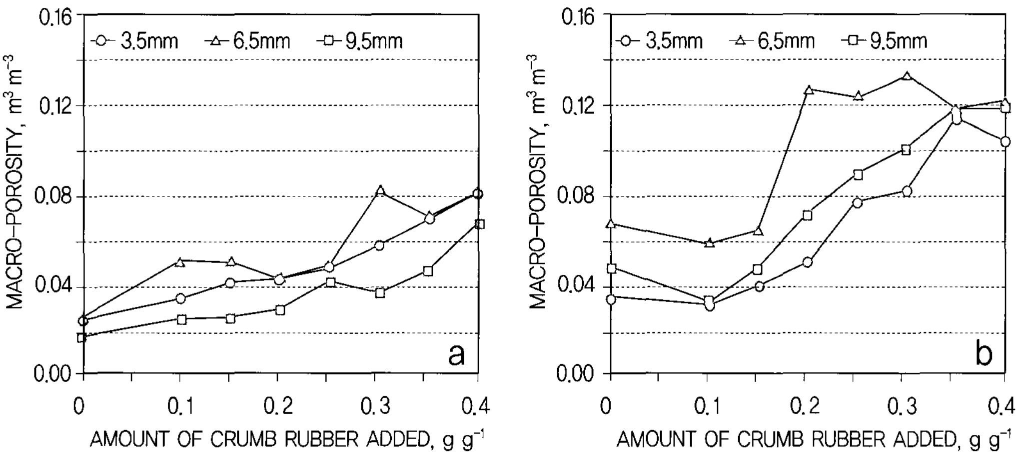

Fig. 2. Changes in macro-porosity measured at-5 kPa in the soil mixes amended with different grades and amounts of crumb rubber. (a) Arenxville silt loam, (b) Hosmer silty clay loam.

increases macro-porosity. Increased macro-porosity will enhance hydraulic conductivity of the mix, hence improving water and air movement in the root zone. In water-logged or highly trafficked areas, incorporation of crumb rubber in soil will definitely be helpful to provide good drainage and relieve problems of compaction.

Saturated Hydraulic Conductivity

The results of saturated hydraulic conductivity, K_{sat} of the mixes for the two soils are shown in Figures 3 (a) and (b), respectively. It is important to note that K_{sat} depends very much upon macro-porosity of the mix. When macro-porosity of the mix increased, the K_{sat} also increased. Similar to the macro-porosity, both Figures 3 (a) and (b) indicated that there was little change in K_{sat} with increasing amounts of crumb rubber up to 0.15 $g \cdot g^{-1}$. But, K_{sat} increased rapidly as the amount of crumb rubber increased beyond 0.25 $g \cdot g^{-1}$. Results also revealed less variability of K_{sat} in the Hosmer silty clay loam mix, particularly at the low level of amendment, compared with the Arenzville silt loam. As shown in Figure 3 (a), the soil mixes of the Arenzville silt loam amended with 3.5 mm crumb rubber had consistently the lowest K_{sat} compared with the 6.5 and 9.5 mm crumb rubber mixes, but the results of K_{sat} with the 6.5 and 9.5 mm crumb rubber mixes were varied. When the amendment increased to 0.4 $g \cdot g^{-1}$, the Hosmer silty clay loam mix had the highest K_{sat} regardless of the grade of crumb rubber. In general, adding crumb rubber to more finely textured soil was more beneficial than adding to the coarse-textured soil for enhancement of soil tilth.

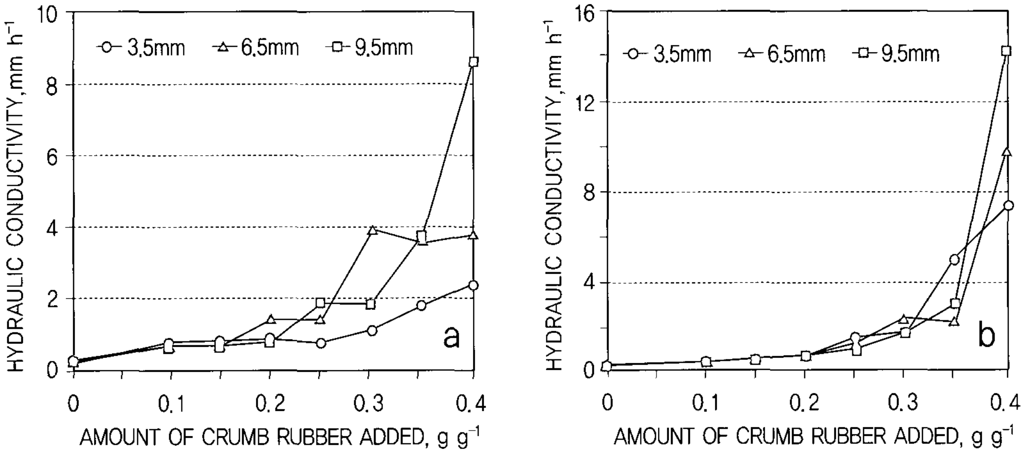

Fig. 3. Saturated hydraulic conductivity of the soil mixes amended with different grades and amounts of crumb rugger. (a) Arenxville silt loam, (b) Hosmer silty clay loam.

Air Permeability

Air permeability is a measure of the rate of air movement in the soil mix. Air permeability in the root zone is particularly important for the evaluation of soil air circulation and/or aeration condition of the root zone.

For a good healthy turf, the CO_2 content in the soil air should be less than 5%(Chong et al., 2000). The CO_2 content in soil air depends very much upon the air circulation in the root zone. Air permeability can be influenced by the air-filled porosity or water content status in the soil mixes. In this study, air permeability of all soil mixes was measured at water content retained at -20 kPa suction. The trends of air permeability, as shown in Figure 4 (a) and(b), of the soil mixes amended with different amounts of crumb rubber were similar to the hydraulic conductivity. When the soil mix was amended with a high rate of crumb rubber both air permeability and K_{sat} values were high.

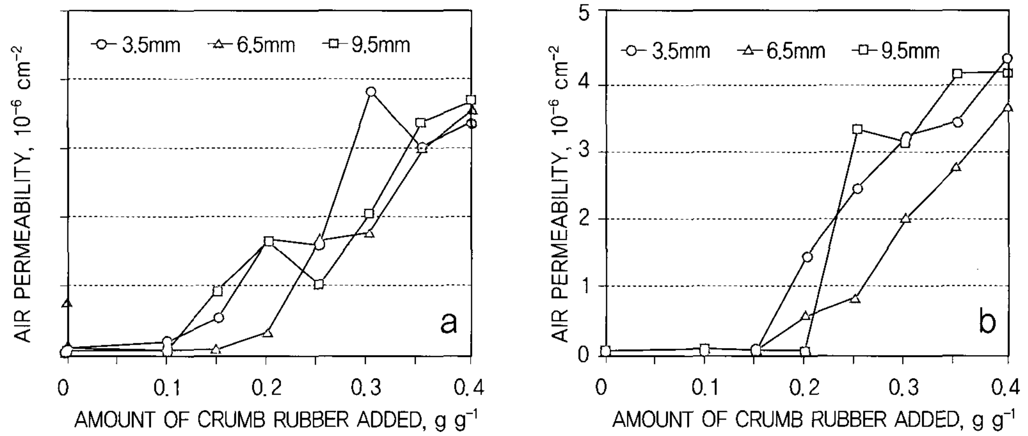

Fig. 4. Air permeability of the soil mixes amended with different grades and amounts of crumg rubber. (a) Arenxville silt loam, (b) Hosmer silty clay loam.

SUMMARY

Based on the laboratory tests, the following conclusions can be made. Regardless of the grade, soil mixes with less than 0.15 g · g^{-1} of crumb rubber in a fine-textured soil had little influence on physical properties of the mixes. Macro-porosity, hydraulic conductivity, and air permeability increased with the amount of crumb rubber amended in the mix. However, total porosity decreased as the amount increased.

국문요약

본 연구는 폐 타이어를 미사질 토양에 혼합하여 경기장 식재층으로서의 질을 향상 시키고자 실시하였다. 특히 본 실험을 통해 토양에 혼합되는 폐 타이어의 입경 크기와 혼합량에 따라 식재층의 토양 물리적 특성을 측정하고자 하였다.

실험에서 두 종류의 토양 [Arenzville silt loam(coarse-silty, mixed, nonacid, mesic Typic Udifluvents), Hosmer silty clay loam(fine-silty, mixed, mesic Typic Fragiudalfs)]과 입경 크기(3.5, 6.5, 9.5mm)에 따라 세 가지의 폐 타이어를 사용하였다. 각각 크기별 토양에 혼합된 폐 타이어의 혼합 비율은 0에서 0.4 $g \cdot g^{-1}$ 사이였다. 각각의 처리구에 대한 실험 진행 및 물리성 조사는 미국 골프협회 Green Section Record 의 기준 방법에 준해서 실시하였다.

본 실험의 결과 토양에 혼합된 폐 타이어의 비율이 증가 할수록 토양의 총 공극량은 감소하였다. 하지만 입경 크기와 상관없이 폐 타이어의 혼합량이 0.15 $g \cdot g^{-1}$ 이하인 경우에는 대공극과 포화투수계수에 차이가 없었다. 반면 폐타이어가 0.15 $g \cdot g^{-1}$ 이상으로 혼합된 토양은 대 공극, 포화 투수계수, 그리고 공기 투과율이 대조구에 비해 통계적으로 유의하게 개선되었다.

주요어 : 개량, 고무칩, 식재층 개량제, 잔디, 토양 물리성

REFERENCES

1. Blake, G.R. and K.H. Hartge. 1986. Bulk density. In: A. Klute(ed.), Methods of soil analysis. Part 1. Physical and mineralogical methods. Agrono. Monogr. 9:363-376. ASA and SSSA, Madison, WI.
2. Boniak, R., S.K. Chong, C.H. Ok, and K.L. Diesburg. 1998. Physical properties and turf quality on soils amended with crumb rubber. p.125. The ASA 1998 Annual Meeting Abstracts. Salt Lake City, UT.
3. Brady, N.C. and R.R. Weil. 1999. The nature and properties of soils. 11th Ed. Prentice Hall, Inc., Upper Saddle River, NJ. 740 pp.
4. Chong, S.K., S. Indorante, D. Buschschulte, and R. Boniak. 2000. Is your turfgrass suffocating, Golf Course Magazine 68(7):72-75.
5. Chong, S.K., C.H. Ok, K.L. Diesburg, and S.J. Indorante. 1998. Changesin porosity of rooting mixtures caused by particle density of the amendment. p.145. The 1998 Annual Meeting Abstracts. ASA, CSSA, and SSSA, Baltimore, MD.
6. Corey, A.T. 1986. Air permeability. In: A. Klute(ed.), Methods of soil analysis. Part 1. Physical and mineralogical methods. Agrono. Monogr. 9:1121-1136. ASA and SSSA, Madison, WI
7. Das, B.M. 1989. Soil mechanics laboratory manual. Engineering Press, Inc., San

Jose, CA.

8. Gee, G.W. and J.W. Bauder. 1986. Particle-size analysis. In: A. Klute(ed.), Methods of soil analysis. Part 1. Physical and mineralogical methods. Agrono. Monogr. 9:383-411. ASA and SSSA, Madison, WI.
9. Goddard, T.M. and L.R. Sabata. 1986. Soil survey of Madison county, Illinois. USDA-Soil Conservation Service. US Government Printing Office, Washington, DC.
10. Groenevelt, P.H. and P.E. Grunthal. 1998. Utilization of crumb rubber as a soil amendment for sport turf. Soil & Tillage Research 47:169-172.
11. Herman, R.J., C.C. Miles, L.A. Dungan, B.E. Currie and P.W. Ice. 1979. Soil survey of Jackson county, Illinois. USDA-Soil Conservation Service. US Government Printing Office, Washington, DC.
12. Hillel, D. 1982. Introduction to soil physics. Academic Press, New York, 364 pp.
13. Klute, A. 1986. Water retention: Laboratory methods. In: A. Klute(ed.), Methods of soil analysis. Part 1. Physical and mineralogical methods. Agrono. Monogr. 9:635-662. ASA and SSSA, Madison, WI.
14. Klute, A. and C. Dirksen. 1986. Hydraulic conductivity and diffusivity: Laboratory methods. In: A. Klute(ed.), Methods of soil analysis. Part 1. Physical and mineralogical methods. Agrono. Monogr. 9:687-734. ASA and SSSA, Madison, WI.
15. Logsdon, G. 1990. New sports fields from old tires. Biocycle 31:44-45, 84-85.
16. Malmgren, R.C., N. Parviz, P N. Soltanpour and J.E. Cipra. 1991. Soil amendments with rubber particles. US patent 5,014,562.
17. Riggle, D. 1994. Finding markets for scrap tires. Biocycle 35(3):41.
18. Rogers, J.N. III, J.T. Vanini, and J.R. Crum. 1998. Simulated traffic on turfgrass topdressed with crumb rubber. Agron. J. 90:215-221.
19. Rogers, J.N. III, T. Vanini, and M. Ventola. 1994. Shredded tires - A new soil amendment. Grounds Maintenance 29(3):42-44, 48-49.
20. Soil Science Society of America. 1996. Glossary of soil science terms. Madison, WI.
21. Spomer, L.A. 1977. Principles of soil preparation for drained golf greens. USGA Green Section Record 15(4):9-12.
22. USGA Green Section Record. 1993. USGA Recommendations for putting green construction. USGA Green Section Record 31(2):1-3.