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*Research Article*

# PHYSICAL PROPERTIES, PERMEABILITY AND RETENTIVENESS OF SILT LOAM AND ITS COMPOSITES WITH SAND FOR CONSTRUCTING CARRYING LAYER OF A FOOTBALL FIELD

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**ABSTRACT**

Physical and water properties of silt loam from the area of planned football field were tested and compared with analogous properties of several composites made in laboratory conditions from the collected material with a dominant sand share. The research was conducted in a view of silt loam and its composites usefulness for constructing a carrying layer of football fields. Water permeability of silt loam and composites, as well as retention abilities were tested. The created composites met the water permeability requirements specified by DIN 18035 standard for constructing carrying layer of football fields. On the other hand, silt loam without sand admixture did not meet the requirements, but revealed a high retention capacity and water availability to plants. Among the composites the best retention capacity characterised the mixtures with the biggest content of silt loam, but the best water availability was registered in composites with medium content of silt loam from the football field area. The obtained results may be useful for more precise determination of the standards for grain size distribution of the composites used for constructing the carrying layer of a football field.

**Keywords:** silt loam, composites, water permeability, retention of soil, water availability.

## INTRODUCTION

Natural turf covered football fields, apart from their shape and geometric dimensions [Żegocińska-Tyżuk 1988] should be characterized by an appropriate abundance in nutrients and proper sorption capacity, but also by high water permeability and retentiveness [Policht_Latawiec 2008, Gołąb and Gondek 2013, Milivojević et al. 2011]. Due to the use of wrong materials and (or) inappropriate construction technologies, the football pitches usually do not meet water permeability requirements [Rajda et al. 2011], and therefore, their functionality is limited. Then grass does not have proper aesthetic values [James et al. 2007a, James et al. 2007b]. On sand grounds during rainless periods, the turf requires frequent sprinkling, otherwise it dries. On the other hand, on compact grounds, football pitch, which usually has a considerable retention capacity, is hardly permeable [Pereira et al. 2007] and at irrigation or excessive rainfall, water stagnates on the field surface and causes falling out of grass. It both cases it causes difficulties for football players; the results of conservation measures are poorer and the maintenance costs of football field grow [James et al. 2007a, James et al. 2007b].

According to Żegocińska-Tyżuk [1988], properly constructed football pitch on compact ground should be made up of two several-centimetre thick layers placed on an appropriate foundation (Figure 1). The carrying layer should be constructed of a mixture (composite) of the indigenous ground from the humus layer and appropriate sand admixture, so that the fraction would be dominant in the composite. A drainage layer built of sand only should be placed under the carrying layer [James et al. 2007b]. Such composition is recommended by DIN 18035 standard [Deutche norm]. The carrying layer composite, at the same time constituting grass root layer should be compacted in order to obtain adequate elasticity and dynamic strength.

Compacted carrying layer at maximum capillary capacity should have water permeability no less than 0.3 mm·min$^{-1}$. It ensures good conditions for excessive rainfall seepage to the drainage layer and drains. The carrying layer should be also characterized by good retention properties, determining the frequency and doses of irrigation, on which grass vegetation and conditions of football filed exploitation depend [Oleszczuk end Truba 2013, James et al. 2007a, James et al. 2007b].

Physical and water properties of indigenous ground from the area of a football field planned in Muchacz were analyzed in the paper and compared with analogous properties of laboratory made ground and sand composites.

Suitability of the tested materials for constructing of the football filed carrying layer were estimated from the perspective of water permeability, but also selected physical properties and retention capacities of the ground and composites were analyzed. The obtained results may be useful for precise formulation of the standards of granulometric composition of composites, but also for the construction of football field planned in Muchacz, in wadowicki county.

## METHODS

### Indigenous ground

Samples used for determining the granulometric composition were collected from 3 shallow pits in the area of planned football field (Figure 2), ground samples from the 5–30 cm humus layer and from 31–45 cm sub-arable layer. For determining physical and water properties, 18 samples with undisturbed structure were collected by means of 100 cm$^3$ rings (3 pits, 2 horizons, 3 replications).

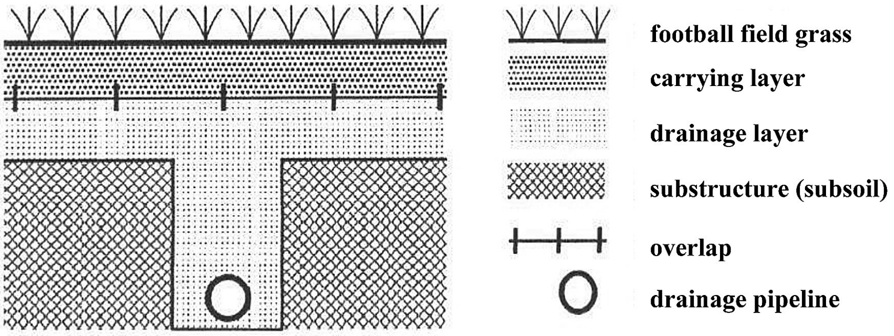
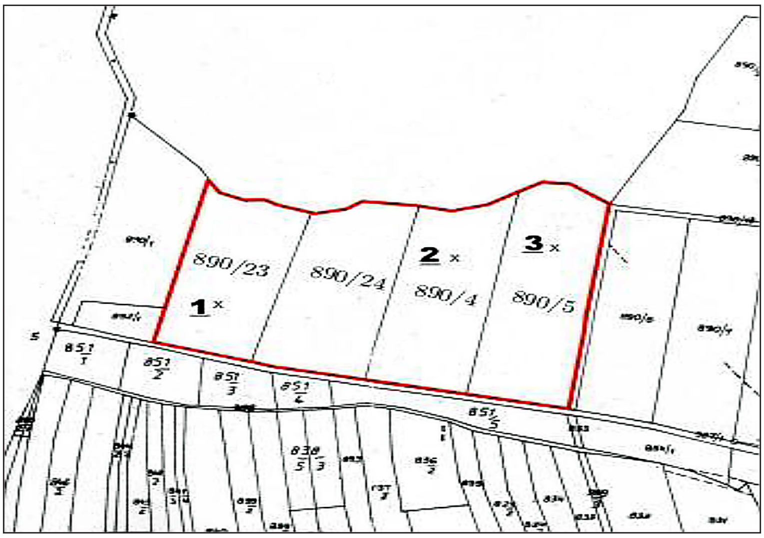


**Figure 1.** Cross-section of grass covered football field on compact ground (according to DIN 18035)



-------- outer boundaries of plots destined for the football field; 1,2,3 – sampling points

**Figure 2.** Distribution of pits in the area of planned football field

Grain size distribution was assessed using Casagrande's sedimentation method in Prószyński's modification, specific density by pycnometer method and bulk density by gravimetric method. Permeability coefficients ($K_{10}^{g}$) were determined by means of laboratory Ejikelkamp permeability meter [Rajda et al. 2011b], whereas water potential ($pF^{g}$), on the basis of which material retention capacity was assessed, in 2-chamber pressure extractor. Assessment of permeability coefficients was conducted depending on the ground permeability at constant or variable water pressure, however, their values were established taking into consideration water viscosity acc. to Ostromecki for water temperature t = 10 °C.

## Composites

6 composites were formed from the indigenous ground, sand and peat substrate (Photo 1) (Photo 2, Table 1) of which a total of 18 samples were collected in three replications to the rings of 100cm$^3$ capacity. Granular composition and physical properties of the composites , except for sand and gravel fractions assessed by sieve method, were analysed in the same way as in case of the indigenous ground. Composite samples were ini-

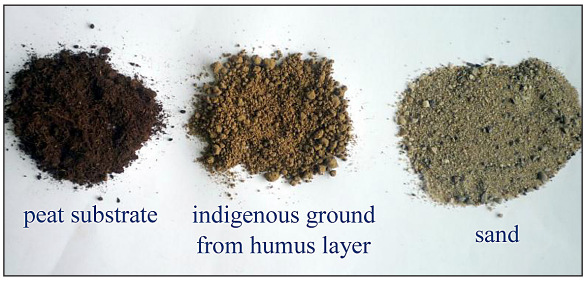


**Photo 1.** Components of the composites

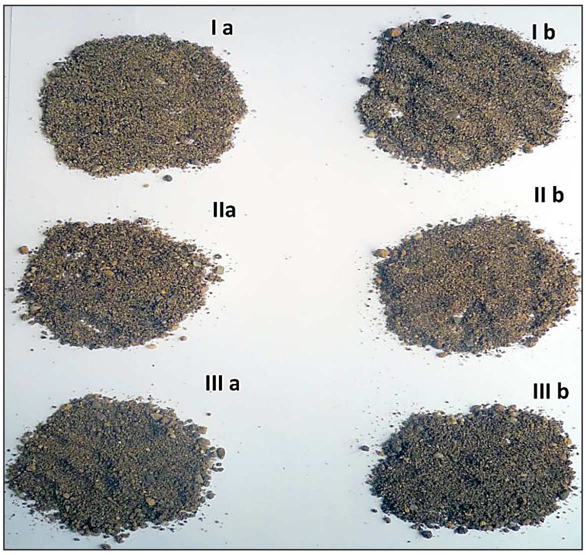


**Photo 2.** Composites

**Table 1.** Weighed portions and planned proportional share of the components in composites

| Composite | Components | | | | Organic matter | | |
|---|---|---|---|---|---|---|---|
| | Symbol | Planned share in composite | | | in component | | in composite [%] |
| | | [g] | | [%] | | | |
| | | at initial moisture | absolutely dry matter | | [%] | [g] | |
| Ia | p* | 1999 | 1998 | 90 | 0.06 | 10 | 1.98 |
| | g* | 215 | 178 | 8 | 2.50 | 4 | |
| | s.o.* | 69 | 44 | 2 | 74.8 | 30 | |
| Total Ia | | 2283 | 2220 | 100 | – | 44 | |
| Ib | p* | 1999 | 1998 | 90 | 0.06 | 10 | 2.97 |
| | g* | 187 | 155 | 7 | 2.50 | 4 | |
| | s.o.* | 104 | 66 | 3 | 74.8 | 49 | |
| Total Ib | | 2290 | 2219 | 100 | – | 63 | |
| IIa | p* | 1790 | 1780 | 80 | 0.06 | 10 | 1.98 |
| | g* | 480 | 400 | 18 | 2.50 | 10 | |
| | s.o.* | 69 | 44 | 2 | 74.8 | 30 | |
| Total IIa | | 2339 | 2224 | 100 | – | 50 | |
| IIb | p* | 1790 | 1780 | 80 | 0.06 | 10 | 3.0 |
| | g* | 460 | 380 | 17 | 2.50 | 9 | |
| | s.o.* | 104 | 66 | 3 | 74.8 | 49 | |
| Total IIb | | 2354 | 2226 | 100 | – | 68 | |
| IIIa | p* | 1560 | 1550 | 70 | 0.06 | 9 | 2.0 |
| | g* | 750 | 620 | 28 | 2.50 | 16 | |
| | s.o.* | 31 | 44 | 2 | 74.8 | 20 | |
| Total IIIa | | 2341 | 2214 | 100 | – | 45 | |
| IIIb | p* | 1560 | 1550 | 70 | 0.06 | 9 | 3.3 |
| | g* | 720 | 600 | 27 | 2.50 | 15 | |
| | s.o.* | 104 | 66 | 3 | 74.8 | 49 | |
| Total IIIb | | 2384 | 2216 | 100 | – | 73 | |

* p – sand, g – indigenous ground, s.o. – organic matter.

tially compacted under pressure of $p_1$ = 12 N·cm$^{-2}$ and their bulk density $p_1$, porosity $n_1$, permeability coefficient $K_1^k$ and water potential – $pF_1$ were assessed. Analogous properties ($p_2$, $n_2$, $K_2^k$ and $pF_2^k$) were determined after compacting under the pressure of $p_2$ = 78 N·cm$^{-2}$.

## RESULTS

### Properties of mineral components

Indigenous ground with its lower proportion in the composites was classified to silt loams with strongly diversified grain size distribution ($U$ = 17.1) In the variation area permitted by DIN 18035 standard it definitely differed from the recommended grain size distribution (Figure 3). In the sub-arable layer (31–34 cm) as compared with the humus layer, granular composition of the ground was more uniform and characterized by a higher share of sand fractions and lower content of organic matter (Table 2).

The sand used for the composites was classified by PN-R-04033 [19] standard to coarse grained deposits (Table 2, Figure 3) with uniform graining ($U$ = 2.1). In relation to the mixtures recommended by DIN 18035 standard for construction of the carrying layer, it contained even about 20% less fractions with diameters smaller than 0.8mm (Figure 3), whose share should be between 10 and 30%. Moreover, it was almost devoid of fractions which are smaller than 0.2 mm and contained a small amount of organic matter.

**Table 2.** Grain size distribution and organic matter of sand and indigenous ground (means from 3 replications)

| Fraction symbol | | Equivalent grain diameters [mm] | Proportional grain content in a component | |
|---|---|---|---|---|
| | | | Sand | Silt loam |
| Clay (i) | | <0.002 | 1 | 15*<br>15 |
| Silt (π) | d | 0.002–0.005 | | 12*<br>10 |
| | s | 0.005–0.02 | | 27*<br>27 |
| | r | 0.02–0.05 | | 31*<br>29 |
| Sand (p) | d | 0.05–0.10 | | 8*<br>8 |
| | | 0.10–0.25 | 2 | 7*<br>11 |
| | s | 0.25–0.50 | 22 | |
| | r | 0.50–1.0 | 52 | |
| | | 1.0–2.0 | 15 | 0<br>0 |
| Gravel (ż) | | 2.0–5.0 | 8 | 0<br>0 |
| Kind of deposit | | | Pg | Gπ*<br>Gπ |
| Effective grain size | | $d_{10}$ | 0.38 | 0.0014 **<br>0.0023 |
| | | $d_{60}$ | 0.80 | 0.024*<br>0.026 |
| | | $d_{90}$ | 1.80 | 0.070*<br>0.130 |
| Index and degree of non-uniformity $U = d_{60}:d_{10}$ | | | 2.1 | 17.1*<br>11.3 |
| | | | uniform grained | very non-uniform grained |
| Organic matter | | | 0.58 | 2.88*<br>1.85 |

* Layer: $\frac{\text{50-30 cm}}{\text{31-45 cm}}$

** Extrapolated from grain-size distribution curves (Figure 3).

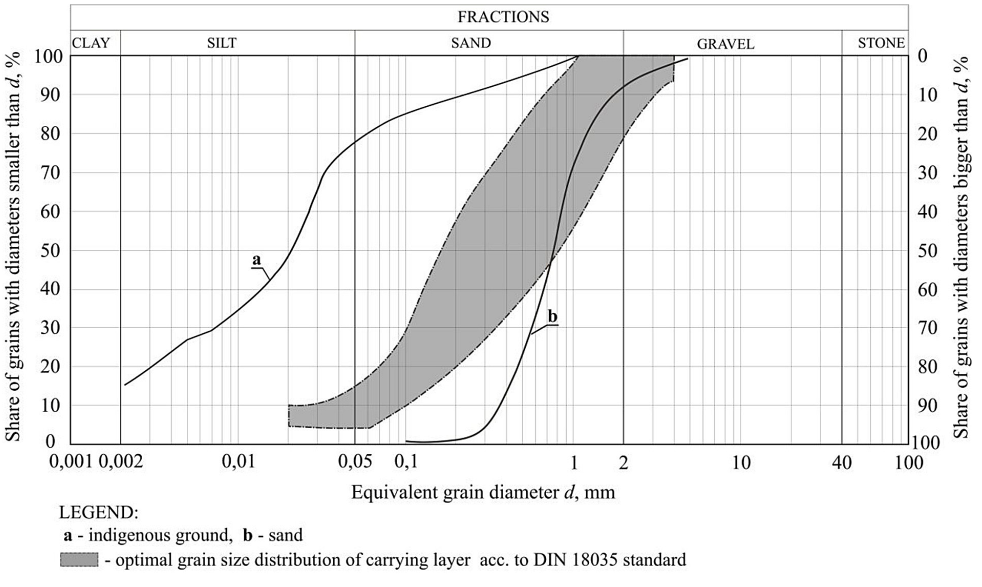


**Figure 3.** Grain-size distribution curves of components against the normal grain-size distribution

**Table 3.** Some physical and indigenous ground properties (means for 3 pits)

| Layer [cm\ | Specific density $\rho_s$ [g×cm$^{-3}$] | Bulk density $\rho_o$ [g×cm$^{-3}$] | Porosity $n$ [%] | Porosity index $e$ [–] |
|---|---|---|---|---|
| Humus 5–30 | 2.64 | 1.42 | 46.2 | 0.86 |
| Sub-arable 31–45 | 2.67 | 1.61 | 39.8 | 0.66 |

Mineral components definitely differed by their equivalent diameters $d_{10}$,$d_{60}$ and $d_{90}$ and the content of organic parts (Table 2).

Due to arable use, bulk density of ground from the humus layer was about 12% (0.19 $g\cdot cm^{-3}$) smaller than bulk density of ground from the sub-arable layer. As a result, total porosity in the ground humus layer was higher in comparison with the sub-arable layer; in this case the absolute difference was 6.4%$_{vol.}$ (Table 3).

## Properties of composites

Grain size distribution of composites mostly differed from the assumptions for the benefit of sand and gravel fractions (see Table 1 and 4). In composites Ia and Ib sand and gravel fractions constituted, respectively 90% and 94% in comparison with the assumed 90%. In composites II and IIb they made up respectively 86% and 89%, in relation to assumed 80%, whereas in composites III a and IIIb – 75% and 79% against 70% (see: Table 1 and Table 4). Composite I was classified to uniform grained deposits, the other two to very non-uniform grained. Equivalent diameters of the composites were also different, particularly $d_{10}$, whereas grain non-uniformity indices differed to a lesser degree (Table 4).

Composite II proved the best adjusted to the normal grain size distribution interval. In comparison with the permissible grain size distribution interval, composite I contained between several and over 10% less of 0.2–0.8 mm fractions in relation to the lower limit of this interval, whereas composite III had over 10% more of fractions smaller than 0.05 mm in relation to the interval upper limit (Figure 4).

Bulk density of equally compacted composites changed slightly with increase in the content of fine particles and 1% higher content of organic matter (variant b of the composites) (Table 5). At compaction pressure $p_1 = 12\ N\cdot cm^{-2}$, bulk density of the composites was higher than the density of indigenous ground from the humus layer, where after compacting under $p_2 = 78\ N\cdot cm^{-2}$ pressure it was also higher than ground density from the sub-arable layer (see Table 5 and 3). Total porosity formed accordingly. After compacting under pressure of $p_2 = 78\ N\cdot cm^{-2}$ it diminished definitely in comparison with the porosity obtained after compacting under the pressure of $p_1 = 12\ N\cdot cm^{-2}$, but due to grain size distribution, both values were clearly lower than the indigenous ground porosity. Increase in organic matter content (variant *b* of the composites) was visible as a slight increasing tendency of porosity (Table 5).

Considering the organic matter composites Ia and Ib met the assumed research requirements, whereas composites IIa and IIb and IIIa and IIIb contained respectively 0.6% and 0.8% less than the assumed value (see: Table 3 and Table 4).

**Table 4.** Grain size distribution and organic matter in composites (means for 3 replications)

| Fraction symbol | | Equivalent grain diameters [mm] | Proportional content in composite | |
|---|---|---|---|---|
| | | | Sand | Silt loam |
| Clay(i) | | <0.002 | 1 | 15*<br>15 |
| Silt (π) | d | 0.002–0.005 | | 12*<br>10 |
| | s | 0.005–0.02 | | 27*<br>27 |
| | r | 0.02–0.05 | | 31*<br>29 |
| Sand (p) | d | 0.05–0.10 | | 8*<br>8 |
| | | 0.10–0.25 | 2 | 7*<br>11 |
| | s | 0.25–0.50 | 22 | |
| | r | 0.50–1.0 | 52 | |
| | | 1.0–2.0 | 15 | 0<br>0 |
| Gravel (ż) | | 2.0–5.0 | 8 | 0<br>0 |
| Kind of deposit | | | Pg | Gπ*<br>Gπ |
| Effective grain size | | $d_{10}$ | 0.38 | 0.0014 **<br>0.0023 |
| | | $d_{60}$ | 0.80 | 0.024*<br>0.026 |
| | | $d_{90}$ | 1.80 | 0.070*<br>0.130 |
| Index and degree of graining non-uniformity $U = d_{60}:d_{10}$ and kind of deposit | | | 2.1 | 17.1*<br>11.3 |
| | | | uniform grained | very non uniform grained |
| Organic matter | | | 0.58 | 2.88*<br>1.85 |

* d – fine. s – medium. r – coarse.

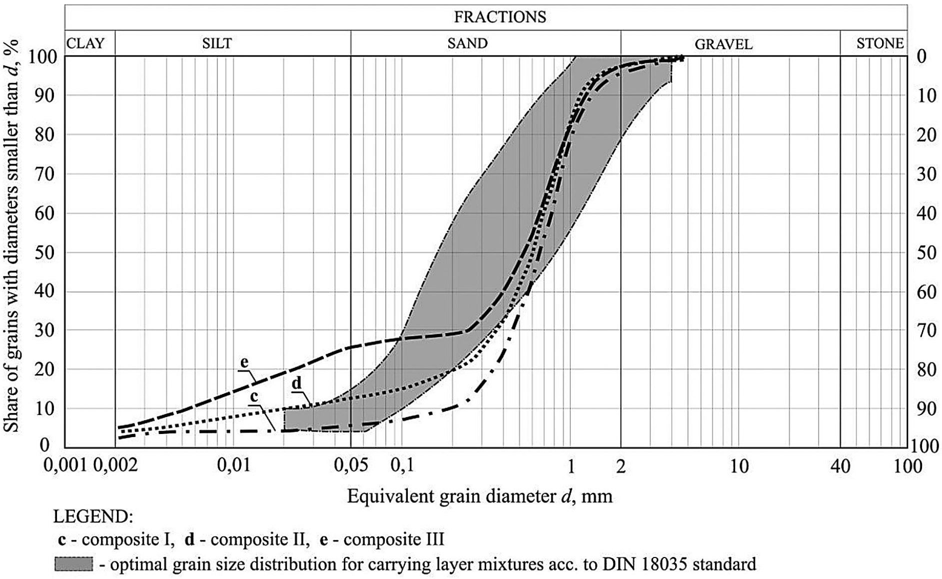


**Figure 4.** Grain size distribution curves against normal grain size distribution interval

**Table 5.** Physical properties ($p_1, n_1, e_1$) and ($p_2, n_2, e_2$) of composites compacted under pressure of respectively: $p_1 = 12\ N \cdot cm^{-2}$ and $p_2 = 78\ N \cdot cm^{-2}$

| Properties | Symbol | Composites | | | | | | Mean I–III | |
|---|---|---|---|---|---|---|---|---|---|
| | | I | | II | | III | | | |
| | | a | b | a | b | a | b | a | b |
| Specific density [g×cm$^{-3}$] | $\rho_s$ | 2.60 | 2.60 | 2.56 | 2.60 | 2.61 | 2.57 | 2.59 | 2.59 |
| Bulk density [g×cm$^{-3}$] | $\rho_1$ | 1.52 | 1.48 | 1.47 | 1.46 | 1.51 | 1.52 | 1.50 | 1.49 |
| | $\rho_2$ | 1.64 | 1.69 | 1.62 | 1.63 | 1.62 | 1.58 | 1.63 | 1.63 |
| Porosity [%] | $n_1$ | 41.6 | 42.8 | 42.6 | 43.9 | 42.2 | 40.9 | 42.1 | 42.5 |
| | $n_2$ | 36.9 | 36.9 | 36.7 | 37.3 | 37.9 | 38.5 | 37.2 | 37.6 |
| Porosity index [–] | $e_1$ | 0.71 | 0.75 | 0.74 | 0.78 | 0.73 | 0.83 | 0.73 | 0.79 |
| | $e_2$ | 0.58 | 0.58 | 0.58 | 0.63 | 0.61 | 0.63 | 0.59 | 0.59 |

## Water permeability and retention capacity of silt loam and composites

Permeability coefficient of silt loam ($K_{10}^{g}$) revealed a high changeability. In the humus layer of respective pits it ranged from 0.15 to 0.26 mm ·min$^{-1}$ with mean for 3 pits and 3 replications 0.23 mm ·min$^{-1}$ (Table 6). In the sub-arable layer mean $K_{10}^{g}$ values fell within the range from 0.000 to 0.005 mm ·min$^{-1}$ and classified the material to impermeable deposits.

Diminishing sand proportion in the composites and increase in silt and clay fractions from the admixture of silt loam caused a decrease in permeability coefficient ($K_{10}^{k}$) – especially after compaction under the pressure of $p_2 = 78\ N \cdot cm^{-2}$ leading to a significant decrease in porosity (Table 7 and 5). At the biggest share of silt loam and considerable grain non-uniformity (composite III), after compacting under the pressure of $p_1 = 12\ N \cdot cm^{-2}$, permeability coefficient $K_{10}^{k}$ decreased by about 2.5-fold on average for variants a and b, in comparison with composites I and II (Table 7), whereas at the same grain size distribution relations, after compaction under the pressure of $p_2 = 78\ N \cdot cm^{-2}$ it changed almost 15-fold in comparison with the mean for composites Ia and Ib and about 4.5-fold as compared with composites IIa and IIb (Table 7).

The increase in organic matter content, on average from about 2.5% (composite variant *a*) to over 3.5% (variant *b*), at compaction under the pressure of $p_1 = 12\ N \cdot cm^{-2}$, was visible for composites II and III as a slight decrease in permeability coefficient, whereas at compaction under the pressure of $p_2 = 78\ N \cdot cm^{-2}$ no evident effect of organic matter was registered (Table 7).

At high total porosity silt loam was characterized by a considerable retention capacity and water availability to plants (Table 8, Figure 5). Differences in moisture for pF 2.5 and pF 4.2 de-

**Table 6.** Permeability coefficient $K_{10}^{g}$ of silt loam [$mm \cdot min^{-1}$] (means for 3 replications)

| Layer [cm] | Pit No. | | | Mean for layer |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| 5–30 | 0.15 | 0.26 | 0.29 | 0.23 |
| 31–45 | 0.005 | 0.003 | 0.000 | 0.003 |

**Table 7.** Permeability coefficients $K_{10}^{k}$ [$mm \cdot min^{-1}$] of composites compacted under the pressure of $p_1 = 12\ N \cdot cm^{-2}$ and $p_2 = 78\ N \cdot cm^{-2}$ (means for 3 replications)

| For compaction under the pressure | $K_{10}^{k}$ of composite | | | | | |
|---|---|---|---|---|---|---|
| | I | | II | | III | |
| | a | b | a | b | a | b |
| $p_1 = 12\ N \cdot cm^{-2}$ | 9.2 | 15.6 | 15.1 | 9.8 | 6.2 | 3.6 |
| $p_2 = 78\ N \cdot cm^{-2}$ | 5.0 | 6.8 | 1.9 | 1.8 | 0.4 | 0.4 |

termining the content of widely available water in humus layer constituted over 30% of bulk. Easily accessible water (moisture differences at pF 2.5 to pF 3.7) made up 17%, whereas unavailable water (at pF 4.2) was below 10% (Figure 5, Table 8). Less advantageous retention properties of silt loam were in the sub-arable layer.

Composites were characterized by a much worse retention capacity. Subjected to the pressure of $p_1 = 12\ N \cdot cm^{-2}$, at identical values of water potential pF, revealed a lower water content (per $\%_{cap.}$) than composites compacted under the pressure of $p_2 = 78\ N \cdot cm^{-2}$ ($p_2$) (Figure 5, Table 9), however, their grain size distribution had a greater effect on water potential than compaction. Percentage increases in moisture, within the range of pH = 1.6 to pF = 4.2, differed slightly for the respective compaction levels, but for composite III moisture at analogous pF values was about twice higher than the moisture of composite I (Figure 5). The outcome of these relations were small percent differences in water supply, and therefore small, only several millimeter supply in the 15-centimeter composite layer (Table 9).

**Table 8.** Characteristic moisture states and water supply in silt loam (means for 3 replications)

| Layer [cm] | Percentage water content at: | | | | | | Water supply [mm] for 15 cm layer at: | | |
|---|---|---|---|---|---|---|---|---|---|
| | pF 2.5 | pF 3.7 | pF 4.2 | pF 2.5–4.2 | pF 2.5–3.7 | pF 3.7–4.2 | pF 2.5–4.2 | pF 2.5–3.7 | pF 3.7–4.2 |
| 5–30 | 39.8 | 12.8 | 9.7 | 30.1 | 17.0 | 3.1 | 45.2 | 25.5 | 4.7 |
| 31–45 | 35.6 | 19.0 | 16.3 | 19.3 | 16.6 | 2.7 | 29.0 | 24.9 | 4.1 |

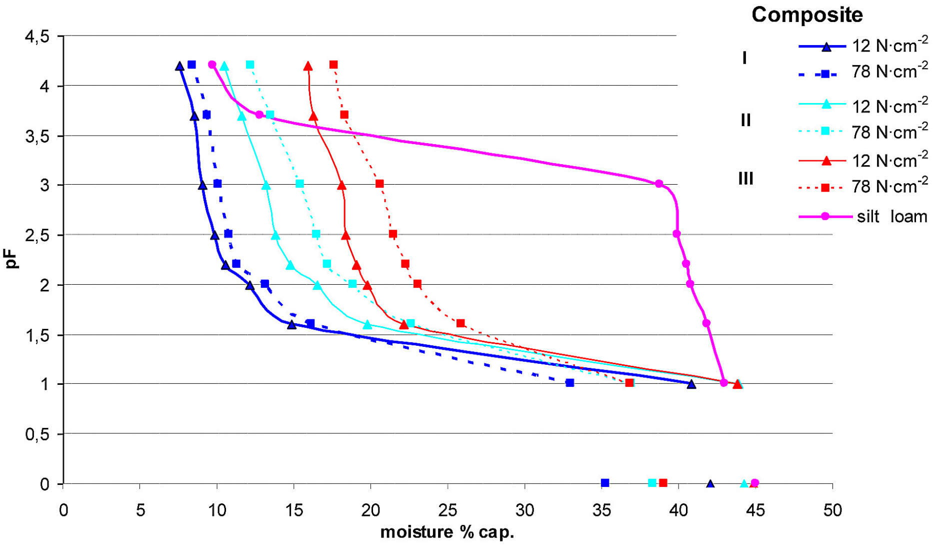


**Figure 5.** Water potential (pF) of silt loam from humus layer and composites (means for 3 replications)

**Table 9.** Characteristic moisture states of composites compacted under the pressure of $p_1 = 12\ N \cdot cm^{-2}$ and $p_2 = 78\ N \cdot cm^{-2}$ and water supply in 15 cm layer (mean for 3 replications)

| Water potential | | Composite | | | | | |
|---|---|---|---|---|---|---|---|
| | | I | | II | | III | |
| | | a | b | a | b | a | b |
| **for $p_1$ = 12 N·cm$^{-2}$** | | | | | | | |
| Moisture in % cap. for: | pF 2.5 | 9.8 | 9.7 | 14.0 | 13.7 | 17.7 | 19.0 |
| | pF 3.7 | 8.1 | 8.9 | 11.3 | 11.9 | 16.0 | 16.5 |
| | pF 4.2 | 7.2 | 7.8 | 10.1 | 10.7 | 15.7 | 16.1 |
| Percentage water content * | OD; pF 2.5–4.2 | 2.6 | 1.9 | 3.9 | 3.0 | 2.0 | 2.9 |
| | ŁD; pF 2.5–3.7 | 1.7 | 0.8 | 2.7 | 1.8 | 1.7 | 2.5 |
| | TD; pF 3.7–4.2 | 0.9 | 1.1 | 1.2 | 1.2 | 0.7 | 0.4 |
| Water supply [mm] * | OD | 3.9 | 2.9 | 5.9 | 4.5 | 3.0 | 4.4 |
| | ŁD | 2.6 | 1.2 | 4.1 | 2.7 | 2.6 | 3.8 |
| | TD | 1.4 | 1.7 | 1.8 | 1.8 | 1.1 | 0.6 |
| **for $p_2$ = 78 N·cm$^{-2}$** | | | | | | | |
| Moisture in % cap. for: | pF 2.5 | 10.2 | 11.4 | 16.4 | 16.5 | 20.5 | 22.5 |
| | pF 3.7 | 9.0 | 9.8 | 13.2 | 13.8 | 17.8 | 18.7 |
| | pF 4.2 | 8.2 | 8.7 | 11.9 | 12.5 | 17.2 | 18.0 |
| Percentage water content * | OD; pF (2.5–4.2) | 2.0 | 2.7 | 4.5 | 4.0 | 3.3 | 4.5 |
| | ŁD; pF (2.5–3.7) | 1.2 | 1.6 | 3.2 | 2.7 | 2.7 | 3.8 |
| | TD; pF (3.7–4.2) | 0.8 | 1.1 | 1.3 | 1.3 | 0.6 | 0.7 |
| Water supply [mm] * | OD | 3.0 | 4.1 | 6.8 | 6.0 | 5.0 | 6.8 |
| | ŁD | 1.8 | 2.4 | 4.8 | 4.1 | 4.1 | 5.7 |
| | TD | 1.2 | 1.7 | 2.0 | 2.0 | 0.9 | 1.1 |

* Widely available (OD), easily accessible (ŁD), hardly available (TD).

The same moisture values and water supplies for 15 cm thick carrying layer of the WISŁA sport club football field were about twice higher than the value obtained for more thickly compacted composites II and III containing less of fine particles than in the compared carrying layer of the football field. On the other hand, moisture values and water supplies in composite I with the lowest content of fine particles (cc. 5%) were approximately equal to the adequate values for the drainage layer on the same football field formed only from the sand Rajda and Kanownik 2006].

## DISCUSSION

Material composed of light loam with 62% content of sand incorporated in 2002 into the 0–40 cm layer during renovation of the WISŁA S.A. sport stadium pitch was characterized by a bulk density of 1.48 g·cm$^{-3}$ and porosity of 40.1%. Analogous parameters of silt loam containing 68% of sand, incorporated into the 40–80 cm layer after compaction were 1.70 g·cm$^{-3}$ and 30.7%. Measured infiltration rate from the field surface was then on the level of 0.040 mm·min$^{-1}$ [Rajda et al. 2011a], i.e. about ten times less than the lowest value recommended by the DIN 18035 standard [Deutche norm]. In result, after heavier rainfall water stagnated on the football field surface. Following the next alteration in 2004, the owners carried out renovation works in compliance with recommendations of the above-mentioned standard: the carrying layer of a composite with 91–95% of sand fraction and underlain by drainage layer had bulk density of 1.40 g·cm$^{-3}$, total porosity 46.7% and permeability of 4.6 mm·min$^{-1}$, while permeability coefficient $K_{10}$ measured in the laboratory in 5 replications, was 13.1 mm·min$^{-1}$ (3.0–24.0 mm ·min$^{-1}$) [Policht-Latawiec 2008, Rajda et al. 2011b]. i.e. on the level corresponding to the analyzed less compacted composites I and II with porosity of 42–43%, containing respectively 96 and 98% of sand.

## CONCLUSIONS

On the basis of conducted experiments it was stated that:

1. Composites with various silt loam and sand and organic matter proportions allow to shape water permeability, therefore, the time of water draining from the football pitch surface may be formed according to needs.
2. Apart from grain size distribution, water permeability and retention capacity of the composites were affected by compaction, however greater influence of grain size distribution was marked at stronger compaction.
3. The tested composites fulfilled the requirements of DIN 18035 standard for water permeability of the carrying layer of the football field; even composite IIIb with the highest share of silt loam and compacted under the pressure of 78 N·cm$^{-2}$ also met the requirements.
4. Increase in the share of fine particle fraction considerably affected water permeability of the composites, but to a lesser extent their water capacity.

5. Increasing the content of organic matter from 2.5% to over 3.5% did not influence water permeability or water capacity of the composites.
6. Composites IIIa and IIIb revealed the highest retention capacity, whereas composites IIa and IIb were characterised by the best water availability to plants.
7. At sprinkling of 15-centimeter thick carrying layer formed of composites IIa and IIb, a single sprinkling dose, considering the drainage layer, should not exceed 10mm (10 dm$^3$ per 1 m$^2$).

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