Evaluation of the Playing Surface Hardness of an Infilled Synthetic Turf System

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Keywords: artificial turf, Gmax, ASTM F355 Impact Test, Clegg Impact Soil Tester, surface hardness, sports turf

Abstract

New configurations of synthetic turf, infilled systems, have been introduced into the market place. These infilled systems are comprised of vertical fibers that are much longer than traditional synthetic turf and can be filled with sand and crumb rubber (infill media). The objective of this study was to evaluate the surface hardness of varying configurations of an infilled synthetic turf system called SofSport™ under wet and dry conditions. Specifically, we wanted to 1) determine the effect of underlying pad thickness and type, infill media depth, sand sizes, and sand to crumb rubber ratio, on surface hardness as measured by the F355 method and the CIST and 2) compare the F355 method with the CIST to determine if one method is preferred when testing synthetic infill systems. Surface hardness differences between pad thickness and types were small but all pad treatments had lower surface hardness values compared to the no-pad treatments. Infill media depth did not affect surface hardness under dry conditions. Under wet conditions, the 38 mm infill media depth resulted in lower surface hardness than the 25 mm depth. The mixing of sand and crumb rubber infill media resulted in lower surface hardness values than sand or crumb rubber alone. When mixed with crumb rubber, finer sands measured higher in surface hardness than coarser sands. Under the conditions of this study the relationship between the Gmax values generated by the F355 method can be compared to the values generated by the Clegg Impact Soil Tester using the regression equation F355 x 0.66 - 9.3 = Clegg Impact Soil Tester. The regression coefficient for this equation was 0.95 and indicates that the Clegg Impact Soil Tester would be a suitable device to measure the surface hardness of SofSport installations.

INTRODUCTION

Since synthetic turf was first installed in the Houston Astrodome in 1966, numerous studies have been conducted to evaluate the safety and playability of synthetic surfaces. These studies have included material tests on the traction and hardness of these surfaces (Valiant, 1990; Martin, 1990) as well as epidimeological studies that have counted athlete injuries on synthetic versus natural turfgrass (Powell and Schootman, 1992; Powell, and Schootman, 1993). Different methods of measuring playing surface hardness have been developed for synthetic turf versus natural turfgrass surfaces. For synthetic turf surfaces the U.S.A. standard is the F355 method (American Society for Testing and Materials, 2000a). For natural turfgrass the standard method is the Clegg Impact Soil Tester (CIST) (American Society for Testing and Materials, 2000b). Although both methods determine hardness by dropping a weighted accelerometer on the turf surface, some have stated that these two methods should not be correlated Popke (2002).

A new configuration of synthetic turf has been introduced into the market place. Termed 'infill' systems, these synthetic surfaces are comprised of a horizontal backing supporting numerous vertical nylon or polypropylene fibers. These vertical fibers (pile) are much longer than those of traditional synthetic turf and can be filled with varying types of granulated material (infill media), typically sand and crumb rubber. It is believed that these new infill systems provide athletes with a surface that performs more like natural turfgrass than traditional synthetic turf (Popke, 2002).

As more synthetic turf systems using sand and crumb rubber infill are introduced into the sports surface market, independent data regarding playing surface quality are required to enable consumers to make informed decisions. Questions have been raised about how the surface hardness of these systems is affected by infill media depth and type (ratio of sand to crumb rubber), and the presence, thickness and type of an underlying shock absorbing pad.

The objectives of this study were to evaluate the surface hardness of varying configurations of an infilled synthetic turf system called SofSport™ (Hummer Sports Surfaces, Lancaster, PA USA) under wet and dry conditions. Specifically, we wanted to determine: 1) the effect of underlying pad thickness and type, infill media depth, sand sizes, and sand to crumb rubber ratio, on surface hardness as measured by the F355 method and the CIST and 2) compare the F355 method with the CIST to determine if one method is preferred when testing synthetic infill systems.

MATERIALS AND METHODS

Wooden boxes (630 mm x 630 mm x 230 mm deep) were constructed in April, 2000. Limestone gravel was packed into each box to within 40 mm of the top using a small hand tamper. One hundred percent of the gravel particles passed a 9.5 mm sieve, 45% passed a 1.0 mm sieve and 7% passed a 0.15 mm sieve.

Shock absorbing underlying pad treatments were placed on top of the gravel in some of the boxes. The underlying pad treatments included: no pad, a 19 mm extruded E-layer pad (Tennis Surfaces Co., Bartlett, IL USA) and a 13 or 19 mm Regupol pad (Dodge-Regupol manufacturing, Lancaster, PA USA). The Sofsport material was then installed over the pad treatment. The Sofsport specifications are shown in Table 1.

Treatments consisting of various depths, sizes and ratios of sand and crumb rubber were worked into the Sofsport pile using brooms and water. This process continued until the desired depth of infill media was achieved. Treatments were either 25 or 38 mm of infill media. The particle size distribution for the sand and crumb rubber is shown in Table 2. The ratio of sand to crumb rubber varied (Table 3). After the infill was worked into the Sofsport pile, the treatments were exposed to the weather for the months of May and June 2000, prior to evaluation. The experimental design was a totally random design with three replications.

The criteria used for comparing treatments were surface hardness measured using a CIST equipped with a 2.25 kg missile and a drop height of 455 mm (American Society for Testing and Materials, 2000b) and the F355 method equipped with a 9.1 kg missile and a drop height of 610 mm (American Society for Testing and Materials, 2000a). Impact attenuation as measured by an accelerometer mounted on the missiles, was used to indicate surface harness and is reported as Gmax, which is the ratio of maximum negative acceleration on impact in units of gravities to the acceleration due to gravity. The average of six CIST and three F355 measurements taken in different locations on each experimental unit (box) was used to represent the surface hardness of that unit. The entire experiment was conducted when the surface was free of moisture from dew or precipitation and was repeated shortly after the treatments were saturated using a hand-held watering device.

The means of the six CIST and three F355 measurements were analyzed using analysis of variance and Fisher's least significant difference test at the 0.05 level. A LSD was not calculated when the F ratio was not significant at the 0.05 level.

RESULTS AND DISCUSSION

Underlying Pad Treatments

In this experiment there were four underlying pad treatments, no pad, a 19 mm extruded E-layer pad, a 13 mm Regupol pad and a 19 mm Regupol pad. For the treatments with 100% sand infill, the two treatments containing an underlying pad (6 and 7) had lower Gmax values than the no-pad treatment (8) under both wet and dry conditions using the CIST and F355 (Table 3). The 13 mm Regupol pad had lower surface hardness values than the E-layer pad when 100% sand infill was tested. However, when the infill was 80% sand and 20% rubber (treatments 1-3) there was no difference in Gmax between the E-layer pad and either thickness of the Regupol pad except when using the F355 method under wet conditions where the E-layer pad had lower G-max values than either Regupol pad. Although differences between pads treatments were found, when the infill contained at least 20% crumb rubber, the differences were small and all pads offered significant impact attenuation compared to the no-pad treatments.

Infill Media Depth

A direct comparison of infill media depth was made using the 50% sand - 50% crumb rubber infill media (Table 3, treatments 10-11). Under these conditions, infill media depth did not affect surface hardness under dry conditions. Under wet conditions, the 38 mm infill media depth had lower Gmax values than the 25 mm infill media depth. This difference was measured with both the CIST and the F355.

Infill Sand Size

Comparing the effect of sand size on surface hardness when 20% crumb rubber was mixed with the sand (Table 3, treatments 2, 4 and 5), the finer Sand A resulted in the highest Gmax values under both wet and dry conditions using either the CIST or the F355. Under wet conditions using the F355, the medium Sand B had higher Gmax values than the coarser Sand C. Under the conditions of this study, when mixed with 20% crumb rubber, the finer sands measured higher in Gmax than the coarser sands.

Infill Sand to Crumb Rubber Ratio

The 100% crumb rubber (treatment 12) had Gmax values that were higher than the 50% sand - 50% crumb rubber (treatment 10) under all conditions except when using the F355 method under dry conditions. The 100% sand (treatment 8) was harder than the 50% sand - 50% crumb rubber (treatment 11) under all conditions. The Gmax values of the 80% sand - 20% crumb rubber (treatment 2) were higher than the 50% sand - 50% crumb rubber (treatment 9) only under dry conditions using the CIST. Although these results do not cover the whole array of possible infill media depths, sand types, and pad types, the mixing of sand and crumb rubber resulted in lower Gmax values than sand or crumb rubber alone under dry conditions (Table 3).

Comparison of Surface Hardness Testing Methods

Under the conditions of this study the relationship between the Gmax values generated by the F355 method can be compared to the values generated by the CIST using the regression equation F355 x 0.66 - 9.3 = CIST. The regression coefficient for this equation was 0.95. Although this study was limited to the Sofsport infill system, the high regression coefficient would indicate that the CIST would be a suitable device to measure the surface hardness of Sofsport installations. The American Society for Testing and Materials (ASTM) has set an upper limit of 200 Gmax on the surface hardness of North American Football Fields as measured with the F355 (American Society for Testing and Materials 2000c). If one or more locations on the tested field result in Gmax values above 200, ASTM specifies that the surface should be replaced in full or in part. Using the above regression equation a Gmax of 200 measured with the F355 would be equivalent to a Gmax of 123 measured with the CIST and a 2.25 kg missile. None of the treatments in this study exceeded the 200 Gmax limit measured with the F355 or the 123 Gmax measured with the CIST.

Since the treatments in this study did not receive any wear due to foot traffic, the Gmax values of the Sofsport treatments are probably representative of the hardness of a newly installed field. The hardness of these treatments after exposure to wear and additional weathering was not measured. Some treatments in this study may have exceeded the upper hardness limit if wear had been imposed. The results of this study should assist consumer's decisions about the presence and type of shock-absorbing pad and the ratio, grade, and thickness of the infill material.

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Tables

Table 1. Sofsport backing and pile specifications (Hummer Sports Surfaces, 2003).

Pile weight	1400 g m^{-2}
Face yarn type	100% Polyethylene
Yarn size	8000 Denier
Construction	Broadloom tufted
Stitch rate	9 stitches per 76 mm
Turfting gauge	10 mm tufting machine
Primary backing	Stabilized woven polypropylene
Secondary backing	560 g polyurethane backing
Total product weight	2450 g m^{-2}

Table 2. Particle size distribution of infill sands and rubber.

Sand Type	% Retained 2.0 mm	1.0 mm	0.5 mm	0.25 mm	0.15 mm	0.05 mm	<0.05 mm
Sand A	0.0	0.0	1.9	50.2	42.8	4.6	0.5
Sand B	0.0	0.3	57.8	36.2	5.1	0.0	0.4
Sand C	0.0	0.2	20.0	40.0	34.0	5.5	0.3

Crumb rubber contained predominance of particles between 0.8 - 1.0 mm

Table 3. Surface hardness of wet and dry synthetic infill surfaces as determined by the Clegg Impact Ttester (CIT) and the ASTM F355 method.

Treatment #	Depth of Infill Media[2] (mm)	Infill Composition[3]	Pad thickness (mm)	CIST Dry	CIST Wet	F355 Dry	F355 Wet
				Gmax[1]			
1	38	80% sand A 20% rubber	19	54.5	54.7	93.9	103.0
2	38	80% sand A 20% rubber	13	58.5	61.5	103.0	103.0
3	38	80% sand A 20% rubber	19[4]	56.8	57.0	98.5	95.5
4	38	80% sand B 20% rubber	13	45.8	46.3	81.8	86.4
5	38	80% sand C 20% rubber	13	42.8	42.7	77.3	80.3
6	25	100% sand A	13	56.3	55.0	97.0	106.1
7	25	100% sand A	19[4]	66.5	72.8	112.1	128.8
8	25	100% sand A	--	104.3	100.8	160.6	175.8
9	38	50% sand A 50% rubber	13	53.2	58.8	93.9	106.1
10	38	50% sand A 50% rubber	--	72.3	69.5	118.2	116.7
11	25	50% sand A 50% rubber	--	73.2	77.3	123.2	142.4
12	38	100% rubber	--	81.3	90.7	125.3	154.6
LSD ($p = 0.05$)				3.6	5.6	12.0	4.2

[1]Gmax = maximum value of the G encountered during impact. G = the ratio of the acceleration of the missile during impact to the acceleration due to gravity.
[2]Sofsport pile depth is 51 mm for infill media depth of 38 mm and 38 mm for infill media depth of 25 mm.
[3]Sand and crumb rubber mixed on a volume basis ($m^3 m^{-3}$)
[4]Extruded E-layer pad.