Overview of Proposals for Track Surface Studies

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A Proposal for Engineered Racing Surfaces

Overview

An effort has been ongoing since the summer of 2004 to obtain a large scale database of track performance characteristics which can be used to determine the safety and suitability of tracks for racing (the left hand portion of Figure 1). This effort has focused to date on the development of techniques and on obtaining data from a wide range of track surfaces. Currently, the techniques developed in this effort are for the performance testing of tracks using a biomechanical hoof tester. These techniques are rapidly becoming well accepted. Results that are currently available allow the performance of a large number of tracks and surfaces to be compared. This provides track owners with an ability to ensure that the track is consistent with current practice. What has not yet occurred is that the track performance has not been tied to epidemiological data. So while it is possible for a track to understand that their racing surface is similar to other tracks, it is not currently possible to understand the implications for the horse if the track deviates from the typical track conditions. Work has also been ongoing to make use of ground penetrating radar for inspection of the base on tracks. The ground penetrating radar has the potential to identify one of the most common problems that results in performance issues on race tracks. Clay mineralogy techniques have also been used to supplement existing composition techniques used for characterizing the materials used in dirt tracks. The use of clay mineralogy techniques such as X-ray diffraction has led to an improved understanding of historical differences in race track design.

At the same time this research and engineering effort has been ongoing, the shift to synthetic surfaces has accelerated in the industry. The performance testing methods that were developed in the first part of this project are very well suited for synthetics and even make it possible to compare synthetics surfaces to dirt tracks. However, while dirt tracks have well established range of tests used to maintain the composition of a dirt track, no equivalent set of tests exists for the synthetic surfaces. Controversy has arisen in a number of the synthetic installations regarding the wax content and other composition issues which will need to be monitored with these new surfaces as they are used. This composition work is a critical complement to the performance testing since identification of concerns with the track requires that some knowledge of what may need to be changed in order to correct the performance of the track is available. Work with the composition of synthetic tracks has been proposed and is currently being pilot tested.

Next Steps

The next steps in the development of engineering based track maintenance include both performance based testing and the development of compositional testing for synthetic tracks. The different aspects of the testing are shown in figure 1. The performance testing techniques are the same for synthetic and dirt tracks. The performance testing must move forward on both dirt and synthetic surfaces to minimize the impact on horses that train or race on both types of surfaces. In contrast to performance tests, compositional tests are fundamentally different for synthetic surfaces and have not, to date, been developed. These aspects need to be developed separately. The priority performance based testing projects are:

- Demonstrate the ability of a daily performance monitoring system using the biomechanical hoof to support the maintenance of a synthetic track. During the first meet on a synthetic track numerous lessons must be learned on how to maintain the track and the response to temperature changes. Performance monitoring should be used to help to ensure that the track is consistent safe and not unnecessarily modified during initial work.
- Demonstrate the ability of daily performance monitoring to provide a more consistent dirt track for racing. Using a full suite of testing and monitoring the best performance of a dirt track had to yet been demonstrated. Given current concerns with some of the synthetic surfaces it is likely that a carefully managed dirt track can be competitive with a synthetic surface.

For the compositional testing of synthetic surfaces the priorities are:

- To develop a method to remove the wax from track material so that the wax content of a track may be determined.
- Evaluate the percentage of fiber and rubber in a synthetic track materials
- Determine at what temperatures critical transitions will occur in synthetic race track surfaces.

In addition, longer term use of these synthetic tracks will be easier and safer for the horses if the expected changes can be predicted. As a result, the accelerated testing of the effects of heat and ultraviolet light on the track materials is an additional issue that must be addressed. The accelerated testing is a lower priority for immediate industry needs, but will become increasingly important as the industry faces issues which will occur after the track has been used for period of time, and also to develop the specific mitigation protocols for the track surfaces.

Perhaps the most obvious issue for future work is the need to document maintenance protocols that are used on different tracks. In particular the maintenance of the surfaces and the adaptation of the maintenance strategies based on the temperature of the track must be documented and made available to all of the tracks using synthetic materials. However, as we develop a strategy for understanding the track surface, it is critical that we understand that none of this work will have a significant impact on the safety of the horse unless it is tied to epidemiological work. These final two aspects of the work are crucial to improving the safety of the tracks for racing.

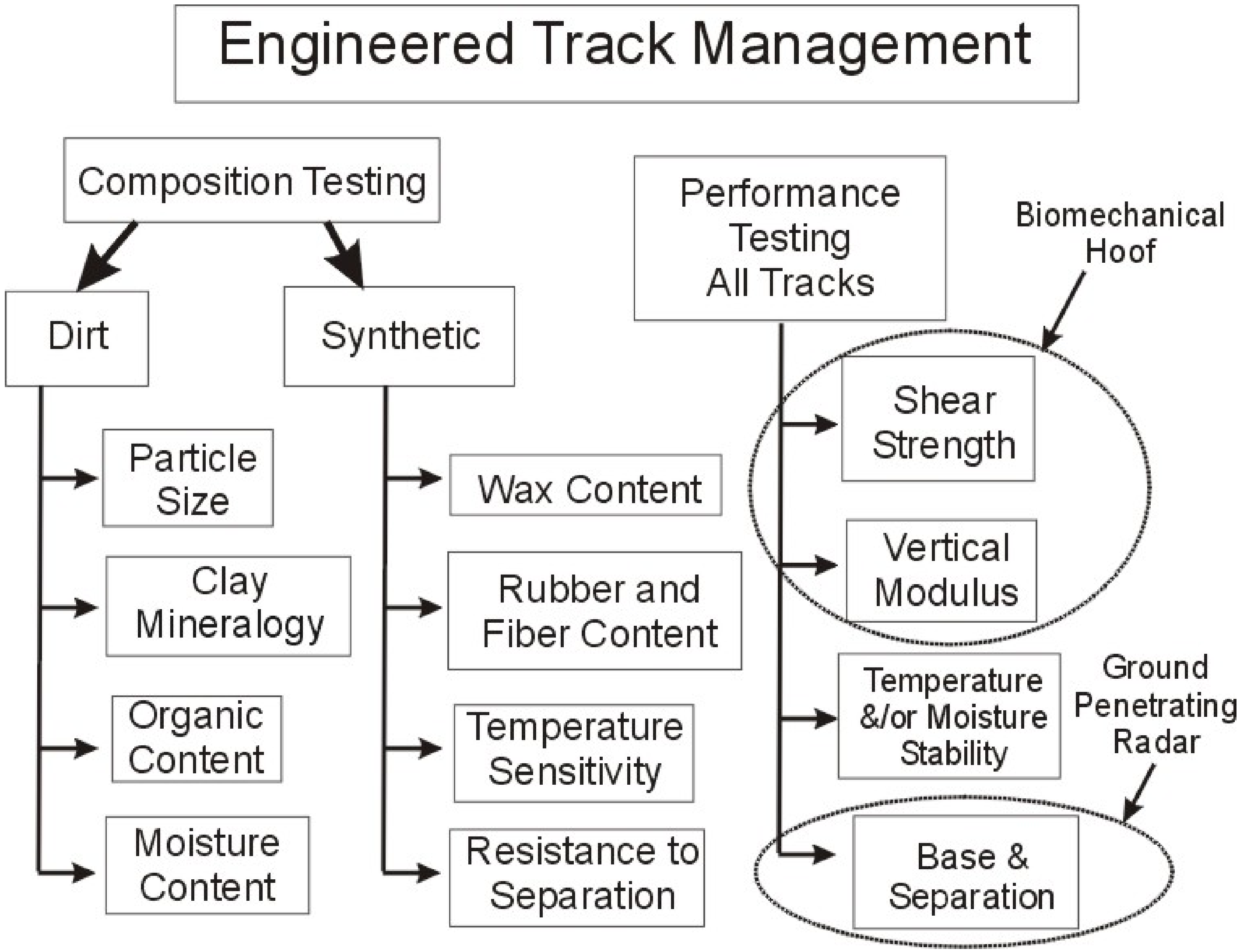

Figure 1: A chart of the tests which can be used to manage racing surfaces.

Proposals

Currently the following proposals are pending with the associated sources of support. Following the list shown above, the priority performance based testing projects are:

- Proposal 1 – Page 7, Synthetic Performance Testing Monitoring
  Pending with Arlington Park.
  Demonstrate the ability of a daily performance monitoring system using the biomechanical hoof to support the maintenance of a synthetic track. This would provide a solid basis for understanding the changes in tracks over time and with different maintenance protocol. $51,213
- Proposal 2 – Page 8, Measurement of Performance Parameters and Engineered Management on a Dirt Track
  No current pending source of support
  Demonstration of the management of a dirt track to minimize variability and support the maintenance of the track. $44,120
- Proposal 3 – Page 9, Thermo-Gravimetric Characterization of Synthetic Track Composition
  Pending with Martin Collins LLC
  A method must be developed to remove the wax from track material so that the wax content of a track may be determined and to evaluate the percentage of fiber and rubber in synthetic track materials. $34,848
- Proposal 4 – Page 15, The Effect of Temperature on Synthetic Surface Materials
  Pending with Martin Collins LLC & Del Mar Thoroughbred Club
  A proposal to determine at what temperatures critical transitions will occur in synthetic race track surfaces was submitted to the sport horse portion of Martin Collins LLC and to Del Mar Thoroughbred Club. This was resubmitted on May 4, 2007 when further questions regarding the temperature response arose. It is critical that we understand these transition temperatures so that maintenance of the surface can be adapted. $31,405
- Proposal 5 – Page 21, Documentation of maintenance procedures on synthetic track surfaces.
  No current pending source of support
  Currently maintenance procedures for synthetic tracks are not standardized. This will develop into a larger problem if over time various schools of through develop on the proper maintenance of these tracks which will lead to variability between tracks and perhaps at a single track. This proposal focuses on the documentation of current practices and the development of a guide for best practices in maintenance of synthetic rack surfaces.
  $86,552 with biomechanics work included

- Proposal 6 – Page 25. Proposal for Comprehensive Testing of Synthetic Track Surfaces for Durability and Safety
  The larger proposal includes most of the other efforts for epidemiology as well as linkages to biomechanics, has been distributed to a number of organizations. Craig Fravel at Del Mar received this in June of 2006 and several other organizations have received copies of this proposal. The most likely funding of this effort would be in sections that appeal to different constituencies and immediate needs of the industry.
  $211,731 which includes proposal 3 and 5 also listed separately above

The most important unfunded initiatives at this time are, in order of importance:

1. Demonstrate the ability of a daily performance monitoring on synthetic and dirt surfaces
2. A technique to determine at what temperatures critical transitions will occur in synthetic race track surfaces
3. Documentation of maintenance procedures on synthetic track surfaces.

Proposal 1. Synthetic Performance Testing Monitoring Arlington Park – 2007

This proposal is for the monitoring of the new synthetic surface at Arlington Park Raceway. The intent of the proposed work is to understand the in-situ thermal response of the track material and to provide baseline data for the performance of the surface. The primary focus of the testing will be on the use of the biomechanical hoof tester and ground penetrating radar as track management tools. The work will, however, also include composition analysis of the surface and testing of standard in-situ monitoring tools. The outcomes of the summer efforts will be:

- Daily data on the dynamic modulus and shear strength of the new Arlington Park Track surface on a using the Biomechanical Hoof tester
- Weekly monitoring of the density of the track material using ground penetrating radar
- Development of a test which will allow the modulus of the material to be measured at a range of temperatures over the course of the summer
- Monitoring of the performance of the track under a full range of temperatures encountered during the meet
- Composition analysis of the track on a weekly basis, including the wax, sand, rubber and fiber composition of the surface at three different depths and four different locations

All data will be analyzed and a weekly report will be submitted that will allow the performance of the track to be evaluated over the course of the meet and the period of the testing. Daily data will be available from testing within 24 hours of acquisition in order to ensure complete feedback for maintenance and communication of track conditions to constituents.

Patrick Kuo			
Labor & Expenses	Assumes 5/20/07 to 8/30/07		
	Room (Extended Stay Hotel)	$55	$5,610
	Per Diem (75% of federal)	$48	$4,896
	Salary ($1000/wk)	$143	$14,571
	Mileage -- Maine to Arlington	$0	$948
	All costs charged at actual expense		
Mick Peterson			
Labor & Expenses	3 trips, 2 days work + 2 days travel		
	Travel, Airfare	$600	$1,800
	Per Deim	$64	$768
	Time	$1,100	$6,600
	Travel Time	$320	$1,920
	Rental Vehicle	$200	$600
	Insurance, Peterson Prof. Liability	$250	$1,500
	All costs charged at actual expense		
Equipment			
	Vehicle Adaptation	$900	$900
	Weekly Rate Hoof (equivalent to 2 days/w	$640	$9,600
	Daily Rate Radar (2 days/wk)	$100	$1,500
	Rates based on maintenance and cost		
		Total	$51,213

Proposal 2: Measurement of Performance Parameters and Engineered Management on a Dirt Track

This proposal is for the monitoring of the dirt track surface at a racing venue with a short meet. The intent of the proposed work is to understand the response of the track to a standard strategy of maintenance inputs and to determine if changes from compaction moisture and organic content can be managed to create a surface which is comparable to synthetic surfaces in consistency. The primary focus of the testing will be on the use of the biomechanical hoof tester and ground penetrating radar as track management tools. The work will, however, also include composition analysis of the surface and testing of standard in-situ monitoring tools. The outcomes of the summer efforts will be:

- Daily data on the dynamic modulus and shear strength of the track surface using the Biomechanical Hoof tester
- Weekly monitoring of the density of the track material using ground penetrating radar
- Monitoring of the moisture content of the track under a full range of evaporation rates and water application strategies encountered during the meet
- Composition analysis of the track on a weekly basis, including the particle size analysis, analysis of the organic content, and X-ray diffraction of the existing and all added material to the track.

All data will be analyzed and a weekly report will be submitted that will allow the performance of the track to be evaluated over the course of the meet and the period of the testing. Daily data will be available from testing within 24 hours of acquisition in order to ensure complete feedback for maintenance and communication of track conditions to constituents.

Graduate Student Labor & Expenses		Day	12 week
	Room (Extended Stay Hotel)	$55	$4,620
	Per Diem (75% of federal)	$48	$4,032
	Salary ($1000/wk)	$143	$12,000
	Mileage -- Maine to Track	$0	$500
	All costs charged at actual expense		
Mick Peterson Labor & Expenses	3 trips, 2 days work + 2 days travel		
	Travel, Airfare	$600	$1,800
	Per Deim	$64	$768
	Time	$1,100	$6,600
	Travel Time	$320	$1,920
	Rental Vehicle	$200	$600
	Insurance, Peterson Prof. Liability	$250	$1,500
	All costs charged at actual expense		
Equipment			
	Vehicle Adaptation	$900	$900
	Weekly Rate Hoof (equivalent to 2 days/w	$640	$7,680
	Daily Rate Radar (2 days/wk)	$100	$1,200
	Rates based on maintenance and cost		
		Total	$44,120

Proposal for Thermo-Gravimetric Characterization of Synthetic Track Composition

Michael "Mick" Peterson, PhD

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Executive summary:

The development of synthetic surfaces has the potential to be the most important change in horse racing facilities in decades. In order to realize the full potential from this investment in synthetic tracks, best practices for quality control and maintenance must be developed. Quantitative measures of the track composition are a critical part of both quality control and maintenance.

Currently tests do not exist for characterizing the quantities of the constituent materials in a synthetic track. Therefore, a new test must be developed to quantitatively measure the proportion of each of the constituent materials in new and existing installations. This test will help to eliminate unintentional differences in installed surfaces. The test can also provide quality control to ensure that the track mixture has the intended composition at all locations. Finally, such a test will also be used to maintain the proper composition of the track over time. Immediate funding is needed to develop the test methods for the track materials and to obtain baseline tests on existing surface materials.

It should be emphasized that this proposal is for the design of a new test. While the new test is based on well established techniques in polymer analysis, the new test requires design of special equipment and development of baseline results for these materials. The test methods will be developed in this work and then will be made available to interested parties. While there is some technological risk associated with the development of these tests, the risk is low given the widespread use of related techniques by polymer chemists.

Background

This proposal is part of a larger research effort which has been presented in total and in separate sections for particular constituencies. The goal is to develop test methods which can be used to support biomechanical and epidemiological research to understand and reduce risks from racetrack surfaces. The particular method proposed in this section of the proposal can be used to assist in the quality control during installation of synthetic surfaces as well as the maintenance and monitoring of the track surfaces. The proposed effort will result in the development of the required test methods and will establish the infrastructure needed to support the tracks during the installation and use of these new synthetic surfaces. Broad dissemination of lessons from the maintenance of these surfaces will result not only a safer surface for the horses, but also reduced maintenance cost. The proposed approach is modeled on other sports, most notably European football (soccer)[1] and the American National Standards for synthetic turf [2]. Test methods from other sports are used when they are applicable. However, the unique materials as well as the loads and speeds associated with horse racing require that in some cases new tests must be developed that are specific to horse racing. This proposal is part of a forward looking approach which has the potential to assist the entire industry.

Track Materials Testing

As a part of the larger proposal, the track material testing sequence includes not only the composition test described in more detail below, but also tests of durability and performance that can be done with moderate size samples of the material. These tests can be used to compare the response of different materials and to describe the ability of the material to retain those properties over the expected lifetime of the material. The properties considered in the material tests are simplified from actual usage since they are designed to be performed on small samples of the material. Initial biomechanical testing of the material can also be done in a 1 square meter (10.7 square foot) container on a concrete base which is filled with about 0.15 cubic meters (5 cubic feet) of material. This type of testing allows the materials to be compared under similar conditions and allows the materials to be ranked according to cushioning and shear strength performance under standard temperature conditions. The depth of the material would be the same as that which would be recommended over the base on the track.

The ultimate test of the material is, however, the in-situ testing of the biomechanical performance of the synthetic track material. Ultimately the in-situ testing of the biomechanical performance must be done for the actual installation including the base used on the racetrack. The track material and biomechanical testing allow baseline expectations of the performance of a new facility to be established. This baseline data provides the reference data which will allow maintenance of the surface to be evaluated to ensure that the track response is consistent over time. Measuring the initial performance of these new tracks is critical over the long term. If after some time the inevitable questions arise regarding the performance of the track, testing from the newly installed surface will be available for comparison.

The combination of the laboratory test of the material performance and composition as well as the in-situ testing of the material will provide the information required for proper management of these new tracks. Proper management of these new

[1] Federation Internationale de Football Association, March 2006, "FIFA Handbook of Test Methods for Football Turf", available at http://www.fifa.com/documents/fifa/FQCturf/FQC_Test_Methods_manual_March_2006.pdf

[2] ASTM F 1551, "Standard Test Method for Comprehensive Characterization of Synthetic Turf Playing Materials and Surfaces", ASTM International. Annual Book of ASTM Standards, Vol. 08.01, ASTM International, West Conshohocken, PA.

surfaces will simultaneously ensure the best surface for the horses and protect the significant investment in these new surfaces.

Track Material Test Methods

At least three different types of testing are required to ensure that the track material will be able to sustain the rigors of racing. The first test and the subject of this proposal is a composition test. This test will allow the quantities of the different constituents of the track material to be evaluated to ensure that there is no variation in the properties in different locations on the track, at different depths within the track or that changes occur over time due to loss of material. The second type of testing is durability testing. Using well established techniques from the plastics industries accelerated aging and ultra-violet degradation tests can be performed to help ensure that the track meets all of the required performance criteria for the design life of the track. As a part of the durability testing the thermal response of the material within the operational range must be understood so that accelerated testing may be performed Finally, biomechanical testing can be performed to verify the performance of the track and to ensure that the track meets the best performance expectations when compared to other synthetic and organic track surfaces. A simplified test of the biomechanical performance is also expected to be necessary to ensure that the performance of the track does not change excessively over the range of operating temperatures. This test is, like the other tests described, the subject of a separate proposed initiative. This proposal considers only the determination of the composition of the material by using thermo-gravimetric analysis.

Thermal Measurement of Constituents; Thermo-Gravimetric Analysis

Several of the constituent materials in synthetic tracks area subject to loss and additional material may be need to be refreshed the surface after an installation has been in place for a number of years. Most notably, some of the components of the synthetic track have a lower density. The lower density materials will tend to rise to the top of the track as it is worked depending on the approach to maintenance. The material that accumulates on the top of the track may tend to be lost over time. Additionally, some of the lower melting temperature materials may gradually move downward in the mixture due to gravity and their tendency to creep or flow with time and temperature. These measurements of the quantities of the constituent materials will then provide guidance regarding the amount of material that will need to e added to refresh the surface. Finally, the actual properties of the constituent materials may change with time. Some of these changes may also e datable with by measuring the mass of the more volatile constituents of the wax or polymer such as plasticizers. The use of thermal degradation of the material can be used to measure the quantities of each of the materials. If changes in the mixture occur over time they can be monitored and either the material can be remixed or it can be supplemented to replace material that has been lost either off of the top or into the bottom layers.

The method that is proposed is referred to in the polymer literature as thermo-gravimetric analysis [3]. Thermo gravimetric analysis simply consists of monitoring the weight of a sample with temperature while either keeping the temperature constant or maintaining a constant rate of change. The measurements are carried out in either static or flowing gas which may be inert or active depending on the chemistry of the constituent components that are of interest. Generally most useful for the measurement of the constituents of a heterogeneous mixture is derivative thermo gravimetric analysis where the rate of change of weight with time is plotted with temperature. Rates of heating must be controlled in order to ensure that different polymer mixtures can be compared. But in general, the test simply relies on the fact that the components will volatize or burn at different temperature with time. The exact mechanisms of this process are not simple since typically the polymer is assumed to depolymerize to a monomer which may leave a residue from the degradation of the material while the volatiles such as plasticizers would be lost at much lower temperatures. Thus in some materials, particularly recycled materials, the change over time may be more gradual and harder to characterize than in pure samples.

The analysis of components of a material based on the change in weight is well established for many polymer applications. Standard tests exist such as ASTM D3850[4] and E1131[5] that are used to characterize different materials. Several vendors such as Mettler-Toledo and Shimadzu also sell standard equipment that is used in laboratories throughout the world. However, this equipment is typically used in the synthesis and formulation of polymers and other materials. Thus the sample size used is quite small. The Shimadzu TGA-51 is considered a high capacity machine which means that it can measure up to 2 grams of material with a total prepared sample weight of 10 g [6]. This is not appropriate for the track material since some of the pieces contained in the sample weigh as much as 30 grams or more. After considering some of the current and potential installations it appears that a sample size of at least 200 grams is required to obtain a representative sample of the track. Thus while the technique is well established the use of the method for testing of track materials represents a significant divergence from the standard applications.

This portion of the work will include development of a custom thermo-gravimetric technique and associated development of the equipment. Base line tests will be used on model systems of known composition to evaluate the repeatability of the

[3] Hay, James N., "Thermal Methods of Analysis of Polymers" in *Analysis of Polymer Systems*, Edited by L.S. Bark and N.S. Allen, Applied Science Publishers Ltd. London, 1982, p. 155-169.

[4] ASTM D 3850, "Standard Test Method for Rapid Thermal Degradation of Solid Electrical Insulating Materials by Thermogravimetric Method", ASTM International. Annual Book of ASTM Standards, Vol. 10.02, ASTM International, West Conshohocken, PA.

[5] ASTM E 1131, "Standard Test Method for Compositional Analysis by Thermogravimetry", ASTM International. Annual Book of ASTM Standards, Vol. 14.02, ASTM International, West Conshohocken, PA.

[6] http://www1.shimadzu.com/products/lab/thermal/tga50.html. Shimadzu Corporation, accessed 5-9-06.

equipment that is developed in this method. Different gas compositions will be evaluated to ensure that the test can be performed with a minimal contamination of the sample. The test methods will then be used on material from two existing synthetic track to demonstrate the technique and provide baseline expectations for the repeatability of the test for actual track materials mixtures. Finally a model calibration standard will be developed which is based on an unmixed combination of materials which are intended to represent the typical curve of a racetrack material.

Outcomes & Summary

The overall outcomes of this total research program will include:

- Test protocols for TGA of synthetic track materials that are suitable for use by trained laboratory personnel with access to appropriate equipment that will allow track materials to be compared. The tests will be available on a web site and/or as a publication so that the work can be replicated.
- All test procedures will also be reviewed by outside specialists in the area. They will be reviewed for technical content as well as for applicability to horse racing.
- A laboratory will be set up which will be available at the end of the project to do any of the test procedures listed in the proposal. The individual test costs in the budget provides guidance regarding the expected cost of each tests
- The use of the ASTM or other standards organization will be explored to determine if a modified thermo-gravimetric test could be developed as an official standard for synthetic racetracks.

In summary, the proposed test, thermo gravimetric analysis, is new in this application. While well established in other areas, considerable effort is required to adapt a technique which was designed for a one gram homogeneous sample to a heterogeneous sample of more than one hundred grams. The result will be a test which will allow track owners and track material vendors to ensure that the properties of the material are initially consistent around the track and that they remain consistent over time. The quantity of wax or fiber or other constituents is clearly one of the most critical aspects of these tracks, a quantifiable method of measuring these components is needed. Once the track composition is held constant then issues such as maintenance of the surface and maintenance of the performance can be the focus of future efforts.

Budget

The total cost of development of the technique is $23,728. Individual sample testing would be initially set at $960.80. This cost would drop if higher than anticipated utilization occurred as a result of more widespread adoption of the technique.

Thermo-Gravimetric Testing

		Item	Equipment and Test Set Up: Equipment Cost	Expected Life years	Utilization	Hourly cost	Hours	Test Cost: Cost	Total
Thermo Gravoimetric Testing (TGA) #									
		1100C Oven, open end	$2,100.00	5	5.00%	4.20	4.0	$16.80	
		Ramp PID Controller	$750.00	5	5.00%	1.50	4.0	$6.00	
		Gas Enclosure www.zircarceramics.com	$3,200.00	1	5.00%	32.00	4.0	$128.00	
		Precision Balance	$820.00						
		System Integration	$1,750.00	5	5.00%	3.50	4.0	$14.00	
		Software	$2,500.00						
		Electric Costs						$10.00	
		Test Labor				60.00	8.0	$480.00	
		Reporting Labor				120.00	1.0	$120.00	
Per Sample Costs	$774.80								$774.80
Capital Costs	$11,120.00								
Calibration, 10 samples	$7,748.00								
Particle Size Separation (after TGA)									
		Machine	$2,500.00	5	10.00%	2.50	2.0	$5.00	
		Timer	$500.00	5	10.00%	0.50	2.0	$1.00	
		Test Labor				60.00	2.0	$120.00	
		Reporting Labor				120.00	0.5	$60.00	
Per Sample Costs	$186.00								$186.00
Capital Costs	$3,000.00								
Calibration, 10 samples	$1,860.00								
Total Lab Set Up Costs									
Capital Costs	$14,120.00								
Calibration Costs	$9,608.00								

Set Up Lab	**$25,240**
Calibration Costs	**$9,608**
Total Project Costs	**$34,848**
Per Sample Test Cost	**$961**

http://www.ptli.com/testlopedia/tests/TGA-E1131.asp or better fit: http://www.andersonmaterials.com/tga.html ($240/hr.)

Proposal 4. Composition Testing: The Effect of Temperature on Synthetic Surface Materials

The Effects of Temperature on Synthetic Surface Materials

Michael "Mick" Peterson, PhD

C. Wayne McIlwraith, BVSc, MS, PhD

Executive summary:

The development of synthetic surfaces has the potential to be the most important change in horse racing facilities in decades. In order to realize the potential from the investment in synthetic tracks best practices for quality control and maintenance must be developed. Quantitative measures of the surface performance at usage temperatures have been identified as a critical aspect of both quality control and maintenance.

A new test must be developed for these new surfaces will allow materials to be evaluated for the expected range of temperatures at a track. The performance of these new materials is insensitive to moisture content, however all of these materials respond to ambient temperature. The response to temperature, while less severe than the effects of moisture on a dirt track, are none the less significant. The effect is sufficiently pronounced that on one track, speed records are routinely set at the end of the race card as a result of cooling of the surface. This effect must be quantified so that the best material may be chosen for a particular climate. Funding is required to develop the test methods for measuring these thermal effects and to obtain baseline tests on existing surface materials. At the end a method will be provided and facilities will be available to make testing of materials and replication of the tests possible.

It should be emphasized that this proposal is for the design of a new test. While it is based on established techniques in polymer analysis, it is a new test that requires that special equipment be designed for the testing and methods which will be developed. As such there is some risk associated with the development, but that risk is considered to be low given the widespread use of related techniques.

Background

Synthetic surfaces are based on a mixture of materials such as rubber, sand, wax or oil and fibers. This is an important decision since significant evidence has accumulated that indicates a change to synthetic track material can increase safety of tracks and arena surfaces and can reduce the injury rates for horses.

However, this effort also represents a large scale conversion to a new surface design which has few precedents. While tracks exist in the United Kingdom that have been installed for some period of time, the tradition and style of racing on these surfaces is somewhat different that horse racing in North America. Synthetic training and arena surfaces have also been used for some time, but these materials differ from the current state of the art. More experience exists in the United Kingdom, but the weather and usage is different than many of the United States locations. While it is unlikely that these concerns will result in a surface that is a serious risk to horses; however, the high expectations that will be set when these synthetic surfaces are installed will need to be met in the long term as well as the shorter term.

This proposal seeks to develop a test method which can be used to assist in evaluating the performance of synthetic surfaces over a range of temperatures. A series of related proposals have been submitted to bring together a comprehensive look at the issues such as the maintenance and material monitoring which are associated with these new materials. The proposed effort will result not only in the development of the methods required, but will set up the infrastructure needed to support the tracks during the installation and use of these new synthetic surfaces. Ideally, the wide sharing of the lessons learned from the maintenance of these surfaces can result in not only a safer surface for the horses, but also reduced cost for maintenance and reduced management effort. The proposed approach has models in other sports, most notably European football (soccer)[7] and the American National Standards for synthetic turf[8]. These methods are proposed when applicable, but the loads and speeds associated with horse racing require that the tests be specific. The proposed approach represents a forward looking approach which has the potential to assist the entire industry.

Track Materials Testing

The track material testing consists of composition and durability tests that can be done with small samples of the material and which will describe the ability of the material to retain properties over the expected period of use. The properties considered are simplified since they are designed to be performed on small samples of the material. The biomechanical testing of the material is done initially in a 1 meter square container on a concrete base. This allows materials to be compared under similar conditions and allows ranking of materials for cushioning and shear strength. The depth of the material would be the same as that which would be recommended over the base on the track. Finally, for all materials the biomechanical testing would also be done on an existing installation with the same base proposed for the new facility. The track material and biomechanical testing allow baseline expectations of the performance of a new facility to be established and are key to having a sufficient understanding of the surface to allow maintenance of the surface to be performed.

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[7] Federation Internationale de Football Association, March 2006, “FIFA Handbook of Test Methods for Football Turf”, available at http://www.fifa.com/documents/fifa/FQCturf/FQC_Test_Methods_manual_March_2006.pdf

[8] ASTM F 1551, “Standard Test Method for Comprehensive Characterization of Synthetic Turf Playing Materials and Surfaces”, ASTM International. Annual Book of ASTM Standards, Vol. 08.01, ASTM International, West Conshohocken, PA.

This proposal would develop methods to supplement the testing to which to allow the effect of temperatures on a particular track composition to be tested. The need for this type of testing has been amply demonstrated by the differences in race times as a result of change in temperatures at several of the synthetic track facilities. The test will make use of two simple tests, an ultrasonic transit time test and a cone penetrometer test in a sample of the materials which is held at a constant temperature (an isothermal test). The test will then be repeated for the range of temperatures expected in a particular application.

Related Proposed Track Material Tests

Three different types of testing were previously proposed to ensure that the track material will be able to sustain the rigors of usage. The first is a composition test. This test will allow the quantities of the different constituents of the track material to be evaluated. It is necessary to ensure that there is no variation in properties at different locations on the track or at different depths within the track. Changes also may occur over time due to loss of material. The second type of testing is durability testing. Using well established techniques from the plastics industries accelerated aging and ultra-violet degradation tests can be performed to help ensure that the track meets all of the required performance criteria for the design life of the track. Finally, biomechanical testing can be performed to verify the performance of the track and to ensure that the track meets the best performance expectations when compared to other synthetic and organic track surfaces.

Test of Temperature Effects on Track Materials

The test which would be developed in the proposed work would allow materials to be held at a range of temperatures, equilibrated, and then tested to determine the mechanical response of the materials. Ideally the material would be tested with the full biomechanical response characteristics used in the track testing. This would require that the loads and load rate of the horse hoof be replicated in the tests. However because of the amount of material required to provide a valid test and the need to control the temperature of the material this is not practical. As an alternative, simplified tests that represent the key material characteristics are proposed that can be performed using one cubic foot of material.

The different demands on the track during the different phases of the gait are represented by the two tests which will be performed. During the impact and beginning of the stance phase of the gallop the loading of the foreleg is primarily vertical. However the shear strength of the material must also be sufficiently high to provide a secure surface for locomotion[9]. The horizontal component begins during the stance phase and is associated with the transition from forward motion of the hoof during the swing into the propulsive phase of the gait. This horizontal component occurs because of the need to match the hoof speed to that of the ground during the propulsive phase. Initially, this horizontal component is in the direction opposite to that of the motion of the horse.

[9] Biewner, Andrew A., Animal Locomotion, Oxford University Press, Oxford, p. 50

During breakover, this horizontal load reverses direction in order to provide the propulsive force. The propulsive phase is followed by vertical unloading. As the propulsive phase ends, acceleration occurs during the swing phase to catch up with the forward motion of the horse. In the proposed test both the modulus and the shear strength are measured in a simplified manner to ensure that the response of the track is not excessively influenced by temperature changes. Because the rubber, sand, wax or oil and fibers each influence different aspects of the response and each of the components is affected by temperature in a different way, both modulus and shear strength must be measured.

Ultrasonic testing provides a technique which allows the modulus or stiffness of the material to be tested with a small quantity of material at a range of temperatures and pressures. The proposed test of modulus will make use of a modified version of the ASTM E 494, Standard Practice for Measuring Ultrasonic Velocity in Materials[10]. For this test the track material sample will be compacted following a sequence of standard steps into a thermally conductive isothermal cylinder. The cylinder will be connected to a temperature control system which will allow the standard recirculating chiller/heater to normalize the temperature in the material. Tests of the ultrasonic transit time will then be made at a series of temperatures to develop a temperature response curve for the material. This follows well established standard techniques used in polymer characterization[11].

Shear strength in an isothermal test is somewhat more complex. Typical lab tests of shear strength of soils include direct shear and triaxial tests, both of which are difficult and expensive to perform at a range of temperatures. However modifications of the field tests using with a shear vane, cone penetrometer or standard penetration test provide a reasonable alternative. These are simply relative measures, but the change in these relative measures as a function of temperature can also be characterized using these tests. Using the same isothermal cylinder and recirculating system it is possible to take dynamic penetrometer tests[12] or shear vane tests[13] from the samples which can then be correlated to the observed changes in the material.

For each material a comparison must then be made to known samples to determine if the sensitivity is similar to that of a known reference material over the temperature range of use. Therefore, if a typical usage of a material in Del Mar is over a temperature range of 40°F to 80°F, the response of a material for that track would require less sensitivity to temperature than Woodbine where a temperature range of 0°F to 80°F would be required. This would then be slightly broader than the comparable demands in England of 30°F to 70°F where it would be known what range of parameters would be

[10] ASTM E 494, "Standard Practice for Measuring Ultrasonic Velocity in Materials", ASTM International. Annual Book of ASTM Standards, Vol. 03.03, ASTM International, West Conshohocken, PA.

[11] B. Hartmann, 1980, "Further Mechanical Techniques" in *Methods of Experimental Physics, Vol. 16C, edited by R. A. Fava,* Academic Press, New York.

[12] ASTM "Special Technical Publication #399" ASTM International, West Conshohocken, PA.

[13] British Standards, BS1377-1, 1990, "Methods of test for soils for civil engineering purposes. General requirements and sample preparation" British Standards House, London

obtained in the test, and extensive experience of the horsemen over those surfaces exist. From this it is possible to infer a range of acceptable values for the testing of the surfaces.

Outcomes

The outcomes of this research will include:

- A test protocols that is suitable for use by both field personnel and laboratory personnel that will allow track materials and surfaces to be compared. The tests will be available on a web site or as a publication so that the work can be replicated. The track material vendors would be encouraged to develop either in house labs or to cooperate in using one or more outside labs.
- All test procedures will also be reviewed by outside specialists in the area. They will be reviewed for technical content as well as for applicability to horse racing.
- A laboratory will be set up which will be available at the end of the project to do any of the test procedures listed in the proposal. The individual test costs in the budget provide guidance regarding the expected cost of each test.

Budget

Budget numbers should be rounded to allow this work to be done as a foundation donation. If work as a research project is preferred then a 48% overhead charge will be incurred.

The Effects of Temperature on Synthetic Track Materials

Item	Equipment and Test Set Up Equipment Cost	Expected Life years	Utilization	Hourly cost	Hours	Test Cost Cost	Total
Digital Shear Measurement	4,200	5	20%	$2.10	2.0	$4.20	
Ultrasonic System	6,000	10	10%	$3.00	2.0	$6.00	
UT Digitizer	4,000	5	5%	$8.00	2.0	$16.00	
Control Electronics	3,250	5	10%	$3.25	2.0	$6.50	
Recirculating Chiller	3,200	5	5%	$6.40	2.0	$12.80	
Custom Isothermal Cylinder	3,200						
Programming of System	4,000						
Electric Costs						$10.00	
Test Labor				$30.00	6.0	$180.00	
Reporting Labor				$120.00	1.0	$120.00	
							$355.50

Per Sample Costs	$355.50	
Capital Costs	$27,850.00	
Calibration, 10 samples	$3,555.00	
Total Cost of Project		**$31,405.00**
Cost per Sample Future Tests		**$355.50**

Proposal 5. Composition Testing: The Effect of Temperature on Synthetic Surface Materials

A Proposal for Documentation of Maintenance Procedures

A Portion of a Proposal for Comprehensive Testing of Synthetic Track Surfaces for Durability and Safety

Michael "Mick" Peterson, PhD

C. Wayne McIlwraith, BVSc, MS, PhD

Background

The California Horse Racing Board has passed a motion that may result in all of the major tracks in the state having to install a synthetic track surface by Dec. 31, 2007. Other racetracks across North America are also following the lead of Turfway Park in Florence Kentucky in making a decision to install racing surfaces. These synthetic surfaces are based on a mixture of materials such as rubber, sand, wax or oil and fibers. This is an important decision since significant evidence has accumulated that indicates a change to synthetic track material can increase safety of the tracks and reduces injury rates for horses.

However, this effort also represents a large scale conversion to a new track design which has no precedent. While tracks exist in the United Kingdom that have been installed for some period of time, the tradition and style of racing on these surfaces is somewhat different that horse racing in North America. The weather conditions in the UK are also very different than many of the United States locations being considered. The long term durability of these materials in areas with wide temperature variation may be a consideration. It is unlikely that these concerns will result in a surface that is a serious risk to horses; however, the high expectations that will be set when these synthetic surfaces are installed will need to be met in the long term as well as the shorter term. Most significantly, the existing tracks with synthetic surfaces have variation in composition and the maintenance methods that are required. This variation may be a result of local conditions and the experience of local personnel. However at least a portion of the variability appears to be related to quality control problems in the mixing of the surface materials or variation in the material supplied for the track surfaces.

This proposal seeks to develop a series of test methods which can be used to assist in the quality control during installation of synthetic surfaces as well as the maintenance and monitoring of the track surfaces. The proposed effort will result not only in the development of the methods required, but will set up the infrastructure needed to support the tracks during the installation and use of these new synthetic surfaces. Ideally, the wide sharing of the lessons learned from the maintenance of these surfaces can result in not only a safer surface for the horses, but also reduced cost for maintenance and reduced management effort. The proposed approach has models in other sports, most notably European football (soccer)[14] and the American National Standards for synthetic turf[15]. These methods are proposed when applicable, but the loads and speeds associated with horse racing require that the tests be specific. The proposed approach represents a forward looking approach which has the potential to assist the entire industry.

As a part of the investment in tracks an effort is proposed that will quantify the effect of the new track surfaces on injury rates. Understanding the effect of this investment on the industry is an important component of ensuring proper focusing of limited capital investment dollars. No significant epidemiology work has been done in the past which has focused on injury rates associated with the synthetic surfaces. Anecdotal information is compelling; however some preliminary work has suggested that the potential exists for further improvement of synthetic surfaces. In particular, the injury pattern associated with synthetic surfaces may be different from that seen in traditional turf and dirt surfaces.

Documentation of Maintenance Procedures

One challenge which has faced facilities which install synthetic tracks is the need to develop consistent maintenance protocols. In nearly all cases some local adjustments have been made for conditions and availability of equipment. In particular, a number of the concerns which were initially expressed about the Turfway Polytrack installation were initially attributed to procedures adopted by maintenance personnel at that facility. A standard set of maintenance procedures should be developed with quantitative backing for the outcomes. This way the promise of a track that provides a more consistent surface for the horse with lower maintenance costs can be realized.

Even with tracks that have been designed by the same person and which are of nominally the same composition, significant differences in maintenance have been observed. The documentation of these procedures must accompany the development of repeatable tests to detrain the effects of the tests.

It is proposed in this part of the project that once tracks have been installed that an outside observer travel to the existing synthetic tracks to observe and test the track characteristics. This observation and testing must occur over a sufficiently long period of time to ensure that the entire maintenance protocol performed to the track has been observed and documented and that maintenance changes which are done to respond to different ambient temperatures is documented. Follow up visits over the first two years of operation to determine if the maintenance procedures have been continued and a regular report regarding common practices will be published to provide information for the industry.

[14] Federation Internationale de Football Association, March 2006, "FIFA Handbook of Test Methods for Football Turf", available at http://www.fifa.com/documents/fifa/FQCturf/FQC_Test_Methods_manual_March_2006.pdf

[15] ASTM F 1551, "Standard Test Method for Comprehensive Characterization of Synthetic Turf Playing Materials and Surfaces", ASTM International. Annual Book of ASTM Standards, Vol. 08.01, ASTM International, West Conshohocken, PA.

Biomechanics of Synthetic Track

Preliminary questions have arisen regarding the types of injuries which would be likely to occur on synthetic surfaces. In figure 3 a qualitative description of the forces in a hoof during a gallop are shown. The vertical forces are a maximum in the front leg as well as the maximum horizontal deceleration forces of the hoof. However, during the propulsive phase very high loads and accelerations occur in the rear of the horse. This leads to the hypothesis that will be considered in the epidemiological work that the type of injury that occurs will tend to be influenced by the track surface characteristics. For example high shear strength (fast) tracks would be expected to increase the loads on the rear of a horse and increase the likelihood of hind leg fractures. High vertical stiffness (a hard track) would be more likely to lead to fractures in the front. In order to understand the risks associated with this combination of loading on the hooves the relative magnitude of the forces needs to be known. This effort will make use of five horses trained over a three month period to travel over a force plate at a gallop. The data from this work will include both vertical and horizontal load magnitude at the front and rear of the horse. The force plates will be covered with a synthetic track surface which will include both high shear strength, low vertical modulus material and a high vertical modulus low shear strength material. This will ensure that the adaptation of the gait to the surface is accommodated in the study.

Funding is included for a Mechanical Engineering MS degree student from the University of Maine to work with Raoul Reiser at Colorado State University over a summer on the project. The thesis work and analysis of the data will be completed at the University of Maine while the experimental protocol, will be performed at the Equine Orthopeadic Research Center at Colorado State University.

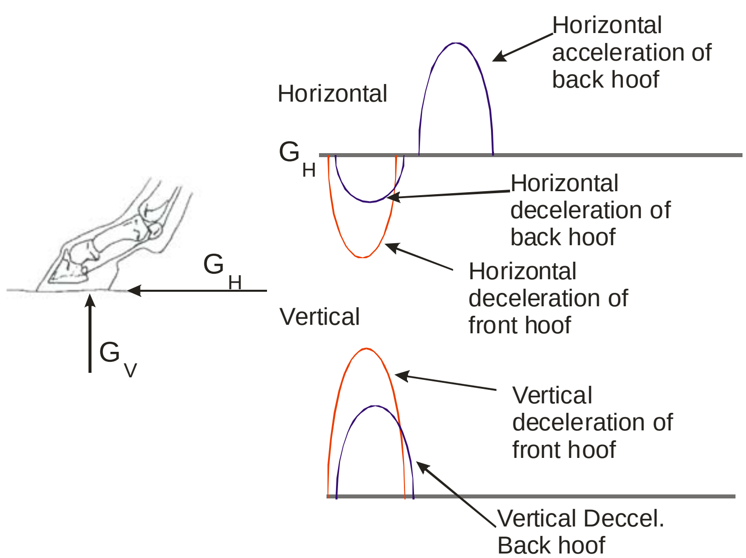

Fig. 3. The forces on the hoof of a horse showing the high propulsive forces (upward pointing curve on top line) in the rear and high deceleration forces (downward curve on top figure) in front. Maximum vertical forces occur in front leg.

Budget

Budget numbers should be rounded to allow this work to be done as a foundation donation. If work as a research project is preferred then a 48% overhead charge will be incurred.

		Months	Rate	Total	
Documentation of Maintenance					
	Mick Peterson (w/38% Fringe)	1	$11,500	$11,500	
	Research Assoc.	12	$1,200	$14,400	
	Travel		$12,000	$12,000	
	Total Maintenance Study				$37,900
Biomechanics					
	Raoul Reiser (w/21% Fringe)	1.5	$7,394	$11,092	
	Graduate Student	12	$1,200	$14,400	
	Graduate Student Housing	3	$900	$2,700	
	5 Horses	3	$2,550	$7,650	
	Horse per deim $17.00	90	$17	$1,530	
	Animal Care Tech.	3	$3,760	$11,280	
	Total Biomechanics				$48,652
Total					$86,552

Proposal 6. Proposal for Comprehensive Testing of Synthetic Track Surfaces for Durability and Safety

Michael "Mick" Peterson, PhD

C. Wayne McIlwraith, BVSc, MS, PhD

Executive summary:

The development of synthetic surfaces has the potential to be the most important change in the maintenance of horse racing facilities in decades. In order to ensure that the potential from the investment in synthetic tracks is met it is necessary to develop best practices for quality control and maintenance. Quantitative measures of the track composition and performance are a critical part of both quality control and maintenance.

A similar approach has been taken in other sports where the American Society for Testing and Materials has developed standards that are used for testing of artificial playing fields for sports. An even better developed set of criterion are used in soccer, where the governing body, Fédération Internationale de Football Association, has produced a comprehensive guide to how to determine if a surface is acceptable for safe and fair play. This guide is a model of what could be done to make horse racing surface maintenance more systematic.

This proposed effort makes use of techniques developed for other sporting surfaces and develops criteria that are suited for the higher loads and speeds seen in horse racing. The proposed standards are based on work that has been done testing both artificial and natural surfaces in the last five years by me and colleagues. The standards developed in this effort would be made available for all of the manufacturers of surfaces and to track owners. Information would be provided so that any or all of the tests could be replicated to develop better surfaces for racing. At the same time the proposed funding would ensure that facilities would be available to perform all of the tests that cannot be done by existing chemical testing laboratories or test organizations. This would ensure that at least one source of quantitative data would be available for determining the suitability of a track for racing.

The first and perhaps most important test to be developed will allow the proportion of the different constituent materials in synthetic track materials to be determined. This test will help eliminate unintentional differences in installed surfaces. The test can also provide quality control to ensure that the track mixture has the intended composition at all locations. Heat and ultraviolet light degradation will be tested using an accelerated method to ensure track durability. The biomechanical performance tests of surfaces that have been developed will also be performed on track material samples at the full range of temperatures expected in the installation. It will then be clear if the track performs acceptably on all days regardless of surface temperature. To determine what benefits accrue from the new surface investments, an epidemiological study will determine the effect of a synthetic track on the injury rate. Additional efforts will include documentation of track maintenance procedures and biomechanics study using synthetic track surfaces.

Immediate funding is needed to develop the test methods for the track materials and for the start of the epidemiological studies. This funding protects the investment in

California tracks and will clarify benefits to horsemen and track owners. The immediate need for funding is $89,000 for the testing method development and $38,000 for the epidemiological study. The biomechanics and track maintenance portion of the work will cost an additional $85,000, but it is less critical that this investment be made prior to the installation of the synthetic tracks.

Background

The California Horse Racing Board has passed a motion that may result in all of the major tracks in the state having to install a synthetic track surface by Dec. 31, 2007. Other racetracks across North America are also following the lead of Turfway Park in Florence Kentucky in making a decision to install racing surfaces. These synthetic surfaces are based on a mixture of materials such as rubber, sand, wax or oil and fibers. This is an important decision since significant evidence has accumulated that indicates a change to synthetic track material can increase safety of the tracks and reduces injury rates for horses.

However, this effort also represents a large scale conversion to a new track design which has no precedent. While tracks exist in the United Kingdom that have been installed for some period of time, the tradition and style of racing on these surfaces is somewhat different that horse racing in North America. The weather conditions in the UK are also very different than many of the United States locations. The long term durability of these materials in areas with wide temperature variation may be a consideration. It is unlikely that these concerns will result in a surface that is a serious risk to horses; however, the high expectations that will be set when these synthetic surfaces are installed will need to be met in the long term as well as the shorter term. Most significantly, the existing tracks with synthetic surfaces have variation in composition and the maintenance methods that are required. This variation may be a result of local conditions and the experience of local personnel. However at least a portion of the variability appears to be related to quality control problems in the mixing of the surface materials or variation in the material supplied for the track surfaces.

This proposal seeks to develop a series of test methods which can be used to assist in the quality control during installation of synthetic surfaces as well as the maintenance and monitoring of the track surfaces. The proposed effort will result not only in the development of the methods required, but will set up the infrastructure needed to support the tracks during the installation and use of these new synthetic surfaces. Ideally, the wide sharing of the lessons learned from the maintenance of these surfaces can result in not only a safer surface for the horses, but also reduced cost for maintenance and reduced management effort. The proposed approach has models in other sports, most notably European football (soccer)[16] and the American National Standards for synthetic turf[17]. These methods are proposed when

[16] Federation Internationale de Football Association, March 2006, “FIFA Handbook of Test Methods for Football Turf”, available at http://www.fifa.com/documents/fifa/FQCturf/FQC_Test_Methods_manual_March_2006.pdf

[17] ASTM F 1551, “Standard Test Method for Comprehensive Characterization of Synthetic Turf Playing Materials and Surfaces”, ASTM International. Annual Book of ASTM Standards, Vol. 08.01, ASTM International, West Conshohocken, PA.

applicable, but the loads and speeds associated with horse racing require that the tests be specific. The proposed approach represents a forward looking approach which has the potential to assist the entire industry.

As a part of the investment in tracks an effort is proposed that will quantify the effect of the new track surfaces on injury rates. Understanding the effect of this investment on the industry is an important component of ensuring proper focusing of limited capital investment dollars. No significant epidemiology work has been done in the past which has focused on injury rates associated with the synthetic surfaces. Anecdotal information is compelling; however some preliminary work has suggested that the potential exists for further improvement of synthetic surfaces. In particular, the injury pattern associated with synthetic surfaces may be different from that seen in traditional turf and dirt surfaces.

The proposal starts with the proposed track materials testing effort in section II. Section III describes a proposed effort to document and standardize the maintenance of synthetic track materials. Section IV describes the proposed study of the effects of synthetic surfaces on the injuries of horses. Section V is a summary of the outcomes of the project and then a budget with itemized details follows.

Track Materials Testing

The track material testing consists of composition and durability tests that can be done with small samples of the material and which will describe the ability of the material to retain properties over the expected period of use. The properties considered are simplified since they are designed to be performed on small samples of the material. The biomechanical testing of the material is done initially in a 1 meter square container on a concrete base. This allows materials to be compared under similar conditions and allows ranking of materials for cushioning and shear strength. The depth of the material would be the same as that which would be recommended over the base on the track. Finally, for all materials the biomechanical testing would also be done on an existing installation with the same base proposed for the new facility. The track material and biomechanical testing allow baseline expectations of the performance of a new facility to be established and are key to having a sufficient understanding of the surface to allow maintenance of the surface to be performed.

Track Material Test Methods

Three different types of testing are required to ensure that the track material will be able to sustain the rigors of racing. The first is a composition test. This test will allow the quantities of the different constituents of the track material to be evaluated to ensure that there is no variation in the properties in different locations on the track, at different depths within the track or that changes occur over time due to loss of material. The second type of testing is durability testing. Using well established techniques from the plastics industries accelerated aging and ultra-violet degradation tests can be performed to help ensure that the track meets all of the required performance criteria for the deign life of the track. Finally, biomechanical testing can be performed to verify the performance of the track and to ensure that the track meets the best performance expectations when compared to other synthetic and organic track surfaces. The following sections will review some of the details of each of the test methods that are proposed

Thermal Measurement of Constituents

Several of the constituent materials in synthetic tracks area subject to loss and additional material may be need to be refreshed the surface after an installation has been in place for a number of years. Most notably, some of the components of the synthetic track have a lower density. The lower density materials will tend to rise to the top of the track as it is worked. The material that accumulates on the top of the track may tend to be lost over time. Additionally, some of the lower melting temperature materials may gradually move downward in the mixture due to gravity and their tendency to creep or flow with time and temperature. Finally, the actual properties of the constituent materials may change with time which will result in losses of material and a change is the properties of some constituents. The use of thermal degradation of the material can be used to measure the quantities of each of the materials. If changes in the mixture occur over time they can be monitored and either the material can be remixed or it can be supplemented to replace material that has been lost either off of the top or into the bottom layers.

The method that is proposed is referred to in the polymer literature as thermo-gravimetric analysis[18]. Thermo gravimetric analysis simply consists of monitoring the weight of a sample with temperature while either keeping the temperature constant or maintaining a constant rate of change. The measurements are carried out in either static or flowing gas which may be inert or active depending on the results that are of interest. Generally most useful for the measurement of the constituents of a heterogeneous mixture is derivative thermo gravimetric analysis where the rate of change of weight with time is plotted with temperature. Rates of heating must be controlled in order to ensure that different polymer mixtures can be compared. But in general, the test simply relies on the fact that the components will volatize at different temperature with time. The exact mechanisms of this process are not simple since typically the polymer is assumed to depolymerize to a monomer which may leave a residue from the degradation of the material while the volatiles such as plasticizers would be lost at much lower temperatures.

The analysis of components of a material based on the change in weight is well established for many polymer applications. Standard tests exist such as ASTM D3850[19] and E1131[20] are used to characterize different materials. Several vendors such as Mettler-Toledo and Shimadzu also sell standard equipment that is used in laboratories throughout the world. However, this equipment is typically used in the synthesis and formulation of polymers and other materials. Thus the sample size used is quite small. The Shimadzu TGA-51 is

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[18] Hay, James N., "Thermal Methods of Analysis of Polymers" in *Analysis of Polymer Systems*, Edited by L.S. Bark and N.S. Allen, Applied Science Publishers Ltd. London, 1982, p. 155-169.

[19] ASTM D 3850, "Standard Test Method for Rapid Thermal Degradation of Solid Electrical Insulating Materials By Thermogravimetric Method ", ASTM International. Annual Book of ASTM Standards, Vol. 10.02, ASTM International, West Conshohocken, PA.

[20] ASTM E 1131, "Standard Test Method for Compositional Analysis by Thermogravimetry", ASTM International. Annual Book of ASTM Standards, Vol. 14.02, ASTM International, West Conshohocken, PA.

considered a high capacity machine which means that it can measure up to 2 grams of material with a total prepared sample weight of 10 g[21]. This is not appropriate for the track material since some of the pieces contained in the sample weigh as much as 30 grams or more. After considering some of the current and potential installations it appears that a sample size of at least 200 grams is required to obtain a representative sample of the track. Thus while the technique is well established the use of the method for testing of track materials represents a significant divergence from the standard applications.

This portion of the work will include development of a custom thermo-gravimetric technique and associated development of the equipment. Base line tests will be used on model systems of known composition to evaluate the repeatability of the equipment that is developed in this method. Different gas compositions will be evaluated to ensure that the test can be performed with a minimal contamination of the sample. The test methods will then be used on material from two existing synthetic track to demonstrate the technique and provide baseline expectations for the repeatability of the test for actual track materials mixtures. Finally a model calibration standard will be developed which is based on an unmixed combination of materials which are intended to represent the typical curve of a racetrack material.

Track Material Durability Testing

Another challenge that faces the new installations of the synthetic tracks is long term durability. While the durability of the tracks has been well established in the UK, the climate and materials used in the North American installations are somewhat different. Most notably, many of the US tracks see far more horse traffic than British courses while in some areas being simultaneously subjected to higher ambient temperatures. A need exists to develop methods that could be used to predict the durability of the materials used in the track surfaces. In particular the plastics, rubber and waxes or oils used in the surfaces are of interest since all of these materials have known thermal and optical degradation mechanisms.

Durability testing of plastics was most rigorously established by the automobile industry in order to provide higher quality dashboards and other interior components that would not cracks as did the early designs from these materials. Later exterior plastic components had to meet even more rigorous standards to avoid not only cracking but to avoid a change in color [22]. These same issues exist in nearly all plastics exposed to intense sunlight and heats. Similarly, temperature related degradation of rubber is a well established issue[23] which emerged in the press only a few years ago related to the Firestone Wilderness AT tires [24]. The waxes used in the synthetic track materials are somewhat less well

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[21] http://www1.shimadzu.com/products/lab/thermal/tga50.html. Shimadzu Corporation, accessed 5-9-06.

[22] SAE J2020, "Accelerated Exposure of Automotive Exterior Materials Using a Fluorescent UV and Condensation apparatus", SAE International, Warrendale PA.

[23] M. L. Peterson and C. Maguire, "The Detection of Matrix Degradation in the Wedge Rubber Compounds" presented at the 174th Technical Meeting of the Rubber Division of the American Chemical Society, October 14-17, 2003, Cleveland Ohio, Published as Paper number 53 from ACS Rubber Division

[24] Office of Defect Detection, 2001, *Engineering Analysis Report and Initial Decision Regarding EA00-023E: Firestone Wilderness AT Tires*, U.S. Department of Transportation, National Highway Traffic Administration, Safety Assurance

understood because of their limited applications in exterior use. However, it is reasonable to state that all of the components of the synthetic track, with the exception of the silica sand, would be subject to environmental aging. Similarly, two mechanisms of aging would be expected for most of these materials. Heat aging can lead to loss of volatiles, plasticizers and other degradations of the structure. Ultra-violet light on the other hand will lead to changes in the material that are generally associated with a change in the number of cross-link between the polymer chains and other similar structural issues. Oxidation of the materials can also occur which is driven by either UV energy or heat.

The goal of the durability testing is to provide information on the types of processes that will occur in track materials and understand if any longer term maintenance will be required. In no case is this expected to be a “deal breaker’, however there may be some differences in performance based on whether the track material uses slack wax, micro-crystalline wax or petroleum jelly as the wax type component.

Heat Aging

The proposed test is based on the ASTM D 3045-92, Standard Practice of Heat Aging of Plastics without Load[25]. The test of modulus will also make use of ASTM E 494, Standard Practice for Measuring Ultrasonic Velocity in Materials[26]. In a wide range of industries it is generally accepted that accelerated aging of materials can be facilitated through the use of elevated temperatures. The materials are heated to a range of temperatures above the operating temperatures but which are below a predetermined proportion of the melt temperature. The material is then tested for operational performance characteristics. After testing for a series of times and temperatures, the portion of the remaining material properties is measured. From this data an estimate of the maximum expected life of the material may be determined. For the purpose of this portion of the testing it is assumed that the modulus of the material is the property of interest of track surfaces. However it goes without saying that more is needed for a full characterization of the track performance. In particular, the shear strength of the material must be optimized in order to provide a secure surface for locomotion[27].

The tests will include two specific aspects, the aging of the sample and the test of the modulus of the material. The aging of the sample will be performed in a test oven. The tests oven will use forced convection to remove volatiles from the testing environment and better replicate the mechanisms for change in the track surface during usage.

The modulus measurement will use standard piezoelectric transducers excited by either a pulse or a tone burst to allow the signal to penetrate a compacted specimen. The signal that has propagated through the compacted specimen will be acquired using a digital storage oscilloscope.

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[25] ASTM D3045-92, “Standard Practice of Heat Aging of Plastics without Load”, ASTM International. Annual Book of ASTM Standards, Vol. 08.01, ASTM International, West Conshohocken, PA.

[26] ASTM E 494, “Standard Practice for Measuring Ultrasonic Velocity in Materials”, ASTM International. Annual Book of ASTM Standards, Vol. 03.03, ASTM International, West Conshohocken, PA.

[27] Biewner, Andrew A., Animal Locomotion, Oxford University Press, Oxford, p. 50

The modulus of the sample is estimated from the wave speed of the ultrasonic wave propagating through the sample. For the estimated wave speed the time delay between the signal and a reference signal is required. The reference signal must be obtained from a known sample with a wave speed that is approximately that of the unknown sample. In this test the reference sample is provided by the control samples which are compacted under the same conditions. The resulting measurements as reported will only be a change in modulus rather than an absolute value. The objective of the test is to determine the drop in modulus during the aging process.

An estimate of the life of the material is developed from the Arrhenius plot[25]. Large errors in the life expectancy can be expected from this plot; however it is well suited for the comparison of track materials if the service life estimated from this method is considered a maximum service life and if it is used for comparison between different track materials.

The Arrhenius plot uses the reciprocal of the temperature of testing versus heat aging time to produce a loss of at least 10% of the modulus. It is expected that this testing will be performed for materials that will in many cases not produce this level of loss in the allotted time. In that case the estimate will be a “greater than n years” estimate of the life of the materials. This estimate will be based on literature for related material classes.

The expected exposure of this material to the elevated temperature will be at least 90 days. From this testing if a consistent degradation of the material is detected then an estimate of the life expectancy may be made. However, if no degradation is detected in this time, it is expected that the life of the material may be quite long. For minimal additional effort the durability testing can be continued beyond the basic 90 days and longer life expectancies of the material can be evaluated.

UV Degradation

Ultraviolet light degradation will be tested in a manner similar to that for the heat degradation. The UV testing can either be performed using natural[28] or fluorescent[29] UV lights. Accelerated testing is typically done with natural light although to properly quantify the exposure is somewhat difficult. It is proposed that since the exposure will be quite different in the tracks of concern, that a more controlled test using artificial light be performed. This will allow the exposure to be better quantified and then to be matched to exposure records for different track locations.

The UV testing of materials, like the heat testing, is typically performed until a defined loss in properties is obtained. This then allows different materials to be ranked for resistance to degradation due to exposure. A valid acceleration factor is not necessarily possible in the case where the materials may change the mechanisms for degradation. However, in this case the degradation of the modulus as used in the heat exposure will be used and the minimum exposure time will be the amount of time required to produce a

[28] ASTM D4364-02, “Standard Practice for Performing Outdoor Accelerated Weathering of Plastics using Concentrated Sunlight”, ASTM International. Annual Book of ASTM Standards, Vol. 14.04, ASTM International, West Conshohocken, PA

[29] ASTM D4329-99, “Standard Practice for Fluorescent UV Exposure of Plastics”, ASTM International. Annual Book of ASTM Standards, Vol. 08.02, ASTM International, West Conshohocken, PA

significant change in the least stable material tested. The materials can then be ranked abased on their stability.

Biomechanical Track Material Testing

The most fully developed of the techniques proposed for testing of track materials is the biomechanical hoof tester. This system has been used on a number of surfaces across the United States to evaluate the compliance of the track surfaces. The device is designed for equine specific measurements; however it is similar to tests done for human athletes for football (US soccer) pitches by the Federation Internationale de Football Association (FIFA)[30]. The biomechanical hoof tester is a device that has been developed with an adjustable speed drop hammer, which impacts the soil at an angle and thus experiences the same horizontal and vertical deceleration that a hoof impacting the soil will experience. The machine uses a synthetic hoof that impacts at the appropriate angle to the soil. The speed of the hoof at impact replicates the velocity of impact of the hoof, with a secondary loading of the hoof through an adjustable gas spring. The adjustable gas spring replicates the compliance of the leg. A stiff mass is attached above the hoof, replicating the mass of the hoof, which initially impacts the track. The horizontal deceleration serves as a test of the horizontal shear strength of the soil.

Data is obtained through the hoof mass that has a three-axis 100 g accelerometer. Load is transferred into a gas spring from the hoof mass using a dynamic load cell with a DC to 36 kHz bandwidth which is used to measure the load due to impact with the soil. The position of the hoof on the drop rail is determined using a string potentiometer. The redundant data from the acceleration and the velocity is used to estimate the penetration into the soil and to verify the velocity of the hoof at impact. Unlike the actual hoof, the angle of the device is fixed during impact. However, the system replicates the strain rate, the loads and the hoof velocity of the horse. Comparison of data from a number of racing venues and types of track surfaces suggest that peak loads on the forelimb of a horse during the gallop vary dramatically. Much of this variation is not predicted by lower strain rate and lower load test methods. Calibration is based on high-speed video data and includes acceleration data obtained from instrumented horseshoes as that data has become available.

Based on these measurements, a quantitative comparison of the effect of different surfaces on the loading of the bones and soft tissue in the horse can be determined. For example, a high sand content material will have low shear strength and low peak loads. A faster surface with higher clay content would be harder (having a higher vertical modulus) and would have higher shear strength. A more complete comparison is important in synthetic surfaces because of the large number of variables which can be altered to produce the desired track characteristics. Unlike an organic track, it is quite straightforward in a synthetic track to create a softer track that is fast. The effects of changes in quantity and type of wax additives, fibers and rubber can be evaluated from the perspective of the effect of the

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[30] Federation Internationale de Football Association, March 2006, “FIFA Handbook of Test Methods for Football Turf”, available at http://www.fifa.com/documents/fifa/FQCturf/FQC_Test_Methods_manual_March_2006.pdf

loads on the horse. By tying this understanding to feedback from the riders and knowledge of the effect on racing outcomes the potential exists to develop a surface which will reliably protect the horses and reduce risks for jockeys and injuries in the horse.

Peak Load

The most basic measurement obtained from the biomechanical hoof tester is the peak load that occurs in the leg directly above the hoof of the horse. This type of a hardness measurement is most closely related to track characteristics that would lead to fracture. Data exists for this measurement for a wide range of track surfaces throughout the United States. The test is also similar to a test, Determination of Shock Absorption (FIFA Test Method 04), used on football pitches in Europe and in international competition[31]. However the loads used are much higher in the horse racing applications because of the higher weight and higher speed of the athlete. Like the tests used by FIFA, these tests should be performed at the full range of temperatures that would be expected in an installation.

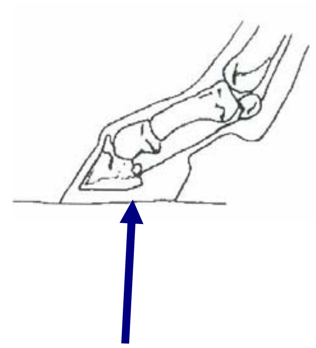

Fig. 1. The arrow is the peak load on the hoof.

[31] Federation Internationale de Football Association, March 2006, "FIFA Handbook of Test Methods for Football Turf", Page 17,

Shear Strength

The other critical design parameter for any track surface is the shear strength of the surface. The shear strength measurement is most closely related to the likelihood of soft tissue injuries in the horse. Low shear strength surfaces are sometimes refer to as being "cuppy" with high shear strength leading to a faster track. Measurements of peak load and shear strength which are often related in an organic track can be changed independently in a synthetic track. Comparison data is currently available for a wide range of tracks and surfaces from across the United States. The test should also be performed at the full range of temperatures that would be expected in any application.

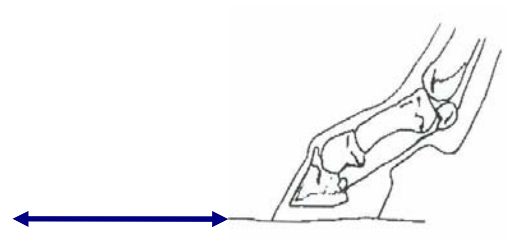

Fig. 2. The arrow shows the direction of the shear strength of the track which is important in hoof strike and propulsion.

Modulus

The peak load of on the hoof is a combination of the effects of the modulus of the surface and the damping of the track material. The current understanding of the track materials is based on measurements and published literature in related materials. However, the relationship between the modulus of the track and the peak load and damping of the material is not well understood. The modulus is a more basic property of the material than the peak load and is also better suited to helping track designers diagnose variation in the track. The data that is currently available from testing of racetracks around the United States can be processed to provide information on the modulus of the track. In this way a more basic measurement of the synthetic track surface can be provided to the track design specialists if questions arise regarding performance of the track. While a significant effort would be required to reprocess the data from the other race tracks around the country this would provide a database of information on the track surfaces.

Damping

The damping properties of the track surface are related to the speed at which the surface responds to loading. In particular they relate the loading of the surface to the displacement of the surface when a dynamic even such as the impact of the hoof on the surface occurs. The higher damping materials are used in tracks as in athletic shoes to reduce the impulsive loading of the bone which can lead to joint disease and which also reduces the peak loading on the bones.

Compaction

Perhaps the most important property of a track surface, organic or synthetic, is the resistance to compaction. The challenge that has continued to face horse racing has been the need to provide a forgiving surface to the horses which is also consistent. After the track has been subjected to traffic from racing or training locations at which hooves have impacted the surface have a peak load that is more than 200% higher than uncompacted regions of the track. In the past compaction has been addressed by implementing equipment and labor intensive maintenance procedures. An acceptable level of compaction will occur if the time between passed from a harrow, a cutting harrow or even a rototiller are appropriately timed. In synthetic surfaces it is possible to obtain consistent performance results from the surface with a much lower level of maintenance of the track because the materials are less sensitive to compaction by the high strain rate impact of the hoof. The amount of increase in loading after multiple impacts with the biomechanical track testing machine is an important measure of the resistance to compaction of the surface. A successful synthetic surface will be able to have multiple hoof impacts without a significant increase in the peak loads or the shear strength of the material.

Documentation of Maintenance Procedures

One challenge which has faced facilities which install synthetic tracks is the need to develop consistent maintenance protocols. In nearly all cases some local adjustments have been made for conditions and availability of equipment. In particular, a number of the concerns which were initially expressed about the Turfway Polytrack installation were initially attributed to procedures adopted by maintenance personnel at that facility. A standard set of maintenance procedures should be developed with quantitative backing for the outcomes. This way the promise of a track that provides a more consistent surface for the horse with lower maintenance costs can be realized.

Even with tracks that have been designed by the same person and which are of nominally the same composition, significant differences in maintenance have been observed. The documentation of these procedures must accompany the development of repeatable tests to detrain the effects of the tests.

It is proposed in this part of the project that once tracks have been installed that an outside observer be travel to a representative sample of tracks to observe and test the track characteristics. This observation and testing must occur over a sufficiently long period of time to ensure that the entire maintenance protocol performed to the track has been observed and documented. Follow up visits over the first two years of operation to determine if the maintenance procedures have been continued and a regular report regarding common practices will be published to provide information for the industry.

Epidemiology of Injuries on Synthetic Tracks

The final missing link on the understanding of the effort and investment in synthetic tracks is an evaluation of the outcomes based on the new tracks. This type of epidemiological study is notoriously difficult in the world of horse racing because of the economic impact of discussing the condition of a horse. However with proper experimental design it is possible to perform this necessary work to understand the costs and benefits of synthetic track designs.

The development of epidemiological method for public health (human) has been very influential in focusing financial resources on areas with high potential for benefit.

> **Epidemiology** is the scientific study of factors affecting the health and illness of individuals and populations, and serves as the foundation and logic of interventions made in the interest of public health and preventive medicine. It is considered a cornerstone methodology of public health research, and is highly regarded in evidence-based medicine for identifying risk factors for disease and determining optimal treatment approaches to clinical practice.[32]

In this case the "intervention" is preventative medicine in the form of synthetic track designs for the reduction of risk to horses.

Basic Epidemiological Study

The proposed epidemiological study will investigate two hypotheses. Hypothesis one will compare the number of injuries requiring euthanasia. The number of these catastrophic injuries will be compared for the same track before and after the installation of a synthetic track. The second hypothesis will consider the effect of installation of the synthetic track on the occurrence of all types of injuries that require a lay-up. Data will be obtained from the trainers on a survey basis and will be based on all horses that leave the barns. Injuries will also be categorized so that any trends in types of injuries associated with the surfaces will be identified.

The monitoring of the injuries will be followed by statistical analysis of the results to determine if the surfaces have an effect on the type and incidence of injuries. The labor involved in this portion of the work includes interaction with track personnel who would know the outcome of horses who were injured and the reporting of other injuries that are not catastrophic.

Biomechanics of Synthetic Track

Preliminary questions have arisen regarding the types of injuries which would be likely to occur on synthetic surfaces. In figure 3 a qualitative description of the forces in a hoof during a gallop are shown. The vertical forces are a maximum in the front leg as well as the maximum horizontal deceleration forces of the hoof. However, during the propulsive phase very high loads and accelerations occur in the rear of the horse. This leads to the hypothesis that will be considered in the epidemiological work that the type of injury that occurs will tend to be influenced by the track surface characteristics. For example high shear strength (fast) tracks would be expected to increase the loads on the rear of a horse and increase the likelihood of hind leg fractures. High vertical stiffness (a hard track) would be more likely to lead to fractures in the front. In order to understand the risks associated with this combination of loading on the hooves the relative magnitude of the forces needs to be known. This effort will make use of five horses trained over a three month period to travel over a force plate at a gallop. The data from this work will include both vertical and horizontal load magnitude at the front and rear of

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[32] Dictionary reference

the horse. The force plates will be covered with a synthetic track surface which will include both high shear strength, low vertical modulus material and a high vertical modulus low shear strength material. This will ensure that the adaptation of the gait to the surface is accommodated in the study.

Funding is included for a Mechanical Engineering MS degree student from the University of Maine to work with Raoul Reiser at Colorado State University over a summer on the project. The thesis work and analysis of the data will be completed at the University of Maine while the experimental protocol, will be performed at the Equine Orthopeadic Research Center at Colorado State University.

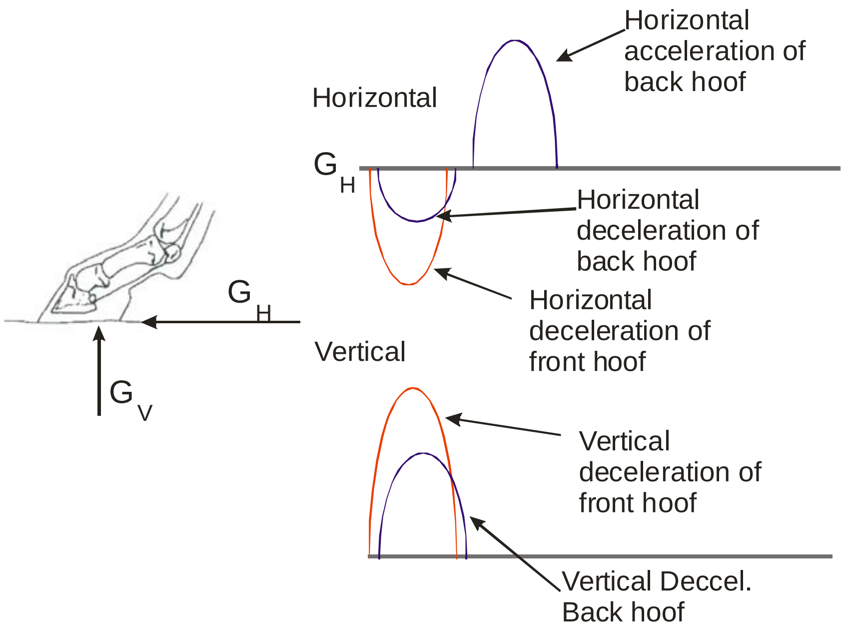

Fig. 3. The forces on the hoof of a horse showing the high propulsive forces (upward pointing curve on top line) in the rear and high deceleration forces (downward curve on top figure) in front. Maximum vertical forces occur in front leg.

Outcomes

The outcomes of this research will include:

- Test protocols that are suitable for use by both field personnel and laboratory personnel that will allow track materials and surfaces to be compared. The tests will be available on a web site or as a publication so that the work can be replicated. The track material vendors would be encouraged to develop either in house labs or to cooperate in using one or more outside labs.
- The design of the biomechanical track tester will be made available for all interested parties. Prints of the current parts as well as specific parts vendors will be available on the project web site. This will allow replication of the system for use at any race track or for use by any of the track material vendors.

- All test procedures will also be reviewed by outside specialists in the area. They will be reviewed for technical content as well as for applicability to horse racing.
- A laboratory will be set up which will be available at the end of the project to do any of the test procedures listed in the proposal. The individual test costs in the budget provides guidance regarding the expected cost of each tests
- A more portable biomechanical track tests system will be developed so that within a reasonable time the biomechanical tests can be performed at any track if questions arise.
- Data will be available to understand the epidemiology of track related injuries. This understanding of track characteristics will allow expectations of all stakeholders to be set as new synthetic tracks are installed. This will also provide baseline data if questions arise in the future regarding new types of injuries or a change in incidence of injuries

Budget

Budget numbers should be rounded to allow this work to be done as a foundation donation. If work as a research project is preferred then a 48% overhead charge will be incurred.

Budget Summary

Test Lab Methods and Equipment			
	Technique Development	$47,469	
	Calibration	$41,268	
	Total		$88,737
Complete Testing of Candidate Surface Prior to Installation (Cost is for each surface considered)			
	Lab Tests	$4,127	
	Field Tests (estimate)	$12,000	
	Total		$16,127
Documentation of Synthetic Track Maintenance Procedures			
	Labor	$26,483	
	Travel	$12,000	
	Total		$38,483
Epidemiology			
	Labor	$32,591	
	Statistical Analysis	$5,000	
	Total		$37,591
Biomechanics of the Synthetic Track			
	Labor	$27,990	
	Horses	$18,930	
	Total		$46,920
Total for Synthetic Racing Surface Initiative			$211,731
Test Cost for Each Candidate Surface			$16,127

Synthetic Track Surface Lab Details

			Equipment and Test Set Up					Test Cost	
		Item	Equipment Cost	Expected Life years	Utilization	Hourly cost	Hours	Cost	Total
Heat Aging									
		Blue M Convection Oven 3 cubic feet	$1,800.00	5	40.00%	0.45	720.0	$324.00	
		Ultrasonic Test	$8,000.00	5	15.00%	5.33	8.0	$42.67	
		Electric Costs						$120.00	
		Test Labor				30.00	4.0	$120.00	
		Reporting Labor				120.00	1.0	$120.00	
Per Sample Costs	$726.67								$726.67
Capital Costs	$9,800.00								
Calibration, 10 samples	$7,266.67								
UV Testing									
Assumes heat testing in place		Solar Light Weatherometer www.solarlight.com	$6,300.00	5	75.00%	0.84	1000.0	$840.00	
		16s-150 Replacement Light 800 hours	$299.00	800				$373.75	
		Ultrasonic Test	$0.00	5	15.00%	0.00	8.0	$0.00	
		Electric Costs						$120.00	
		Test Labor				30.00	8.0	$240.00	
		Reporting Labor				120.00	1.0	$120.00	
Per Sample Costs	$1,693.75								$1,693.75
Capital Costs	$6,599.00								
Calibration, 10 samples	$16,937.50								

Thermo Gravoimetric Testing (TGA) #									
		1100C Oven, open end	$2,100.00	5	5.00%	4.20	4.0	$16.80	
		Ramp PID Controller	$750.00	5	5.00%	1.50	4.0	$6.00	
		Gas Enclosure	$1,200.00	1	5.00%	12.00	4.0	$48.00	
		www.zircarceramics.com							
		Precision Balance	$820.00						
		System Integration	$1,200.00	5	5.00%	2.40	4.0	$9.60	
		Software	$2,500.00						
		Electric Costs						$10.00	
		Test Labor				30.00	8.0	$240.00	
		Reporting Labor				120.00	1.0	$120.00	
	Per Sample Costs	$450.40							$450.40
	Capital Costs	$8,570.00							
	Calibration, 10 samples	$4,504.00							
Ambient Hoof Tester									
		Machine	$50,000.00	5	10.00%	50.00	2.0	$100.00	
		Electronics	$10,000.00	5	10.00%	10.00	2.0	$20.00	
		Mounting Vehicle	$6,000.00						
		Vehicle Modifications	$3,500.00						
		Test Labor				30.00	8.0	$240.00	
		Reporting Labor				120.00	1.0	$120.00	
	Per Sample Costs	$480.00							$480.00
	Capital Costs	$9,500.00							
	Calibration, 10 samples	$4,800.00							

Temperature Controlled Hoof Tester

		Machine	$50,000.00	5	10.00%	50.00	2.0	$100.00	
		Electronics	$10,000.00	5	10.00%	10.00	2.0	$20.00	
		Temperature Controlled Test Cell	$10,000.00	5	5.00%	20.00	2.0	$40.00	
		Electric Costs						$10.00	
		Test Labor				30.00	12.0	$360.00	
		Reporting Labor				120.00	1.0	$120.00	
Per Sample Costs	$650.00								$650.00
Capital Costs	$10,000.00								
Calibration, 10 samples	$6,500.00								

Particle Size Separation (after TGA)

		Machine	$2,500.00	5	10.00%	2.50	2.0	$5.00	
		Timer	$500.00	5	10.00%	0.50	2.0	$1.00	
		Test Labor				30.00	2.0	$60.00	
		Reporting Labor				120.00	0.5	$60.00	
Per Sample Costs	$126.00								$126.00
Capital Costs	$3,000.00								
Calibration, 10 samples	$1,260.00								

Total Lab Set Up Costs	
Capital Costs	$47,469.00
Calibration Costs	$41,268.17
Set Up Lab	$88,737.17
Total Lab Set Up Costs	
Lab Tests	$4,126.82
Field Tests (estimate)	$12,000.00
Total Track Testing	$16,126.82

http://www.ptli.com/testlopedia/tests/TGA-E1131.asp or better fit: http://www.andersonmaterials.com/tga.html ($240/hr.)

		Months	Rate	Total	
Documentation of Maintenance					
	Mick Peterson (w/38% Fringe)	1	$11,500	$11,500	
	Research Assoc.	12	$1,200	$14,400	
	Travel		$12,000	$12,000	
	Total Maintenance Study				$37,900
Epidemiology					
	Wayne McIlwraith (w/21% Fringe)	1	$14,591	$14,591	
	Epidemiologist	3	$6,000	$18,000	
	Statistical Analysis	0.5	$10,000	$5,000	
	Total Epidemiology				$37,591
Biomechanics					
	Raoul Reiser (w/21% Fringe)	1.5	$7,260	$10,890	
	Graduate Student	12	$1,200	$14,400	
	Graduate Student Housing	3	$900	$2,700	
	5 Horses	3	$2,550	$7,650	
	Horse per deim $17.00				
	Animal Care Tech.	3	$3,760	$11,280	
	Total Biomechanics				$46,920
Total					$122,411