In Situ Sampling of Safety Hazards Related to Playground Surfacing and Impact Attenuation Testing with a Variety of Surfacing Materials

CPSC-S-16-0061

Project Title: National Study of Public Playground Equipment and Surfacing
Contract Period: 10.2016 – 2.2018

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Overall Purpose

To develop a methodology and perform in-field assessments of playgrounds in order to discern:

- The general safety status of playground equipment and surfacing throughout the United States; and

- The impact attenuation characteristics of safety surfacing of using a nationally representative sample of public playground surfacing materials.

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Scope of Study

Deliverable #1 Development of a test plan outlining the methodology of a nationally representative sample of public playgrounds and the protocol for data collection procedures.

Deliverable #2 Creation of a safety checklist for identifying the safety concerns of playground equipment and surfacing.

Deliverable #3 Development of an impact attenuation field test data collection sheet.

Deliverable #4 Completion of on-site surface impact attenuation testing and evaluation.

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Project Timeline

November & December 2016
Developed a playground safety checklist, developed impact attenuation data collection sheets, developed testing procedures

January & February 2017
Approval of test plan, wrote letter for permission to test, sample was submitted

February & March 2017
Pilot tested, edits to data collection sheets

March & April 2017
Finalized procedures for data collection sheets and test plan protocol

April & May 2017
Modification to contract to notify playground owners, developed a data entry platform, kick mat procedures

May & June 2017
Testing began, non-compliant surfacing

June & July 2017
87 playgrounds tested with data entry

July & August 2017
103 playgrounds tested, data validation, data analysis

August & September 2017
Progress report submitted

October 2017
Preliminary report and raw data submitted

November 2017 – January 2018
Final Analysis, Final Report, and Raw Data Delivered

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Deliverable #1

Sample Frame Development Methodology

Deliverable #1 Develop a test plan outlining the methodology of a **nationally representative sample** of public playgrounds. Developed a protocol for data collection procedures.

Sample Frame Methodology

- Hired a consultant to get a randomized national sample of public playgrounds.
- Target was to test 400 playgrounds in 3 years.
- Marker placed at each identifiable playground via aerial imagery.
- Validation of identified playground by CSBR (name, address, location type).
- Independent recanvassing of each CBG to identify any missed playgrounds.
- Year One, 2017 tested 103 public playgrounds.

Deliverable #2

Create a Safety Checklist of Equipment and Surfacing

Deliverable #2 Creation of a safety checklist for identifying the safety concerns of playground equipment and surfacing.

- 37 playground safety hazards identified
- Categories of Safety Checklist Questions
  - A) General playground considerations
  - B) General upkeep of playground
  - C) Surfacing
  - D) General hazards
  - E) Security of hardware
  - F) Durability of equipment

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Checklist for Playground Safety Equipment and Surfacing (4/19/2017)

Field tester(s):_____ Date:____/____/____ Start time (AM/PM):_____
City:_____ State:_____

1. Is the playground located in a ☐ Public School ☐ Public Park ☐ Other (Specify)_____
2. How many separate playgrounds are located at this site? (Enter numeral) _____
3. Was one or more picture(s) of each playground taken? ☐ Yes ☐ No
4. From 10am to 2pm, the playground would be in:
   ☐ Full sun ☐ Partial shade ☐ Full shade
5. Are age recommendations posted on playground or equipment? (Check all that apply)
   ☐ Yes, signs posted ☐ Yes, labels on equipment ☐ No
6. Age range of intended user (Check all that apply): ☐ <2 ☐ ages 2-5 ☐ ages 5-12
7. Is a name or phone number posted for the owner/operator? ☐ Yes ☐ No
8. Is there one or more play safety sign(s) posted? ☐ Yes ☐ No
9. What is the estimated age of equipment? (If multiple pieces of equipment, check all ages that apply):
   ☐ <5 years old ☐ 5 to <10 years old ☐ 10 to <20 years old ☐ 20+ years old ☐ Unknown

Part I: General Upkeep of Playgrounds

10. Is the playground clean and free from debris and litter? ☐ Yes ☐ No
11. Are trash receptacles present and not full? ☐ Yes ☐ No
12. Is there graffiti, spray paint, burn marks, or other damage to equipment? ☐ Yes ☐ No
13. Is the playground free from user modifications to equipment (e.g., string and ropes tied to equipment, swings looped over top rail)? ☐ Yes ☐ No

Part II: Surfacing

14. What surfacing materials are present? (Check all that apply)

Loose Fill	Unitary	Inappropriate
☐ Sand	☐ Bonded rubber	☐ Grass
☐ Pea gravel	☐ Poured-in-place	☐ Dirt
☐ Particular rubber padding	☐ Rubber tiles	☐ Synthetic grass w/o padding
☐ Wood product (Specify)	☐ Synthetic grass w/padding	☐ Concrete
☐ Wood chips	☐ Other (Specify)_____	☐ Other (Specify)_____
☐ Wood mulch		
☐ Engineered wood fiber		
☐ Unknown		
☐ Other (Specify)_____		

15. Have surfacing materials deteriorated? ☐ Yes ☐ No
16. Are rubber mats present under heavy use equipment, such as swing and slide exits? ☐ Yes ☐ No
17. If loose-fill surfacing is present: ☐ Check here if loose fill is not present (Skip to Q18 on back).
    a. Is the loose-fill free of foreign debris and trash? ☐ Yes ☐ No
    b. Have loose-fill surfacing materials been displaced under heavy use areas such as under swings or at slide exits? ☐ Yes ☐ No
18. Are there signs of inadequate drainage? (Check all that apply)
    ☐ Yes, equipment ☐ Yes, surfacing ☐ No

Part III: General Hazards

19. Please answer the following questions related to general hazards at this playground.

	Yes	No	N/A
a. Are there sharp points, corners, or edges on the equipment?			
b. Are there missing or damaged protective caps or plugs?			
c. Are there hazardous protrusions?			
d. Are there potential clothing entanglement hazards, such as open s-hooks or protruding bolts?			
e. Are there crush or shearing points on exposed moving parts?			
f. Are there hazards, such as exposed footings or anchoring devices and rocks, roots, or other obstacles in a use zone?			
g. Is there a physical barrier (such as a fence) separating the playground from a steep incline?			
h. Is there a physical barrier (such as a fence) separating the playground from any open bodies of water (lake, fountain, stream, etc.)?			
i. Is there a physical barrier (such as a fence) separating the playground from traffic (could be cars, bicycles, etc.)?			
j. Does design of the guard rails/protective barriers discourage climbing on support structures?			
k. Are guard rails/protective barriers free of openings that could lead to falls?			

Part IV: Security of Hardware

20. Please answer the following questions related to security of hardware at this playground.

	Yes	No	N/A
a. Are there loose fastening devices or worn connections?			
b. Are moving parts, such as swing hangers, merry-go-round bearings and track rides worn?			

Part V: Durability of Equipment

21. Please answer the following questions related to durability of equipment at this playground.

	Yes	No	N/A
a. Is there rust or rot on any equipment?			
b. Are there cracks or splinters on any equipment?			
c. Is there peeling, cracking, or chipping paint on any equipment?			
d. Are there broken or missing components on the equipment?			
e. Are there damaged fences, benches, or signs on the playground?			
f. Is equipment securely anchored?			

22. **Comments**:
_____
_____

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Deliverable #3

Develop Impact Attenuation Field Test Data Collection Sheet

Deliverable #3 Development of an impact attenuation field test data collection sheet.

- Followed ASTM F 1292-13
- Categories
  - A) Surfacing depth measurement
  - B) Air temperature
  - C) Surfacing temperature
  - D) Fall height
  - E) Peak, HIC, and velocity scores

Data Collection Sheet for Impact Attenuation (4/19/2017)

ID:_____

NOTE: The following information should be recorded at the time of the impact test.

Start time	_____ AM/PM
Is there a playground surface material that is appropriate for impact attenuation testing?	☐ Yes ☐ No
Was the test apparatus checked for proper operation for the system integrity check following Section 8.6 and 8.7 ASTM F1292-13 completed?	☐ Yes ☐ No
Was the Instrumentation Check following Section 10 ASTM F1292-13 completed before testing?	☐ Yes ☐ No

Structure number	**Structure #_____**	**Structure #_____**
Play structure?	☐ Composite ☐ Stand-Alone	☐ Composite ☐ Stand-Alone
Age of intended user?	☐ <2 ☐ 2-5 ☐ 5-12	☐ <2 ☐ 2-5 ☐ 5-12
How many types of surface materials in use zone of this structure?		
Equipment material?	☐ Metal ☐ Plastic ☐ Wood ☐ Other: _____	☐ Metal ☐ Plastic ☐ Wood ☐ Other: _____
Test surface material? If multiple surfaces under a structure, indicate using letters (e.g., 1a, 1b...)	**Unitary** ☐ Poured-in-Place ☐ Rubber Tile ☐ Kick Mat ☐ Synthetic grass w/padding ☐ Other: _____ **Loose Fill** ☐ Particular Rubber ☐ Sand ☐ Pea Gravel ☐ Wood Products ☐ Other: _____	**Unitary** ☐ Poured-in-Place ☐ Rubber Tile ☐ Kick Mat ☐ Synthetic grass w/padding ☐ Other: _____ **Loose Fill** ☐ Particular Rubber ☐ Sand ☐ Pea Gravel ☐ Wood Products ☐ Other: _____
Comments		

ID:_____

Drop area		**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**
Equipment type		☐Slide ☐Swing ☐Horizontal climber ☐Vertical climber ☐Bars ☐Other: _____	☐Slide ☐Swing ☐Horizontal climber ☐Vertical climber ☐Bars ☐Other: _____	☐Slide ☐Swing ☐Horizontal climber ☐Vertical climber ☐Bars ☐Other: _____	☐Slide ☐Swing ☐Horizontal climber ☐Vertical climber ☐Bars ☐Other: _____	☐Slide ☐Swing ☐Horizontal climber ☐Vertical climber ☐Bars ☐Other: _____	☐Slide ☐Swing ☐Horizontal climber ☐Vertical climber ☐Bars ☐Other: _____
Pictures taken		☐	☐	☐	☐	☐	☐
Condition of surfacing		☐Dry ☐ Wet ☐ Frozen ☐Other: _____	☐Dry ☐ Wet ☐ Frozen ☐Other: _____	☐Dry ☐ Wet ☐ Frozen ☐Other: _____	☐Dry ☐ Wet ☐ Frozen ☐Other: _____	☐Dry ☐ Wet ☐ Frozen ☐Other: _____	☐Dry ☐ Wet ☐ Frozen ☐Other: _____
Kick mat under loose fill		☐ Yes ☐ No ☐ No loose fill	☐ Yes ☐ No ☐ No loose fill	☐ Yes ☐ No ☐ No loose fill	☐ Yes ☐ No ☐ No loose fill	☐ Yes ☐ No ☐ No loose fill	☐ Yes ☐ No ☐ No loose fill
Loose fill depth: BEFORE tamping		_____ in	_____ in	_____ in	_____ in	_____ in	_____ in
AFTER tamping		_____ in ☐ No loose fill	_____ in ☐ No loose fill	_____ in ☐ No loose fill	_____ in ☐ No loose fill	_____ in ☐ No loose fill	_____ in ☐ No loose fill
Air temp. (F degrees)							
Surfacing temperature (F degrees)							
Fall height (ft)							
Impact 1	**Test #**						
	Peak						
	HIC						
	Velocity						
Impact 2	**Test #**						
	Peak						
	HIC						
	Velocity						
Impact 3	**Test #**						
	Peak						
	HIC						
	Velocity						
Loose fill depth after Impact 3		_____ in ☐ No loose fill	_____ in ☐ No loose fill	_____ in ☐ No loose fill	_____ in ☐ No loose fill	_____ in ☐ No loose fill	_____ in ☐ No loose fill
Was the Instrumentation Check following Section 10 ASTM F1292-13 completed after testing?							☐ Yes ☐ No

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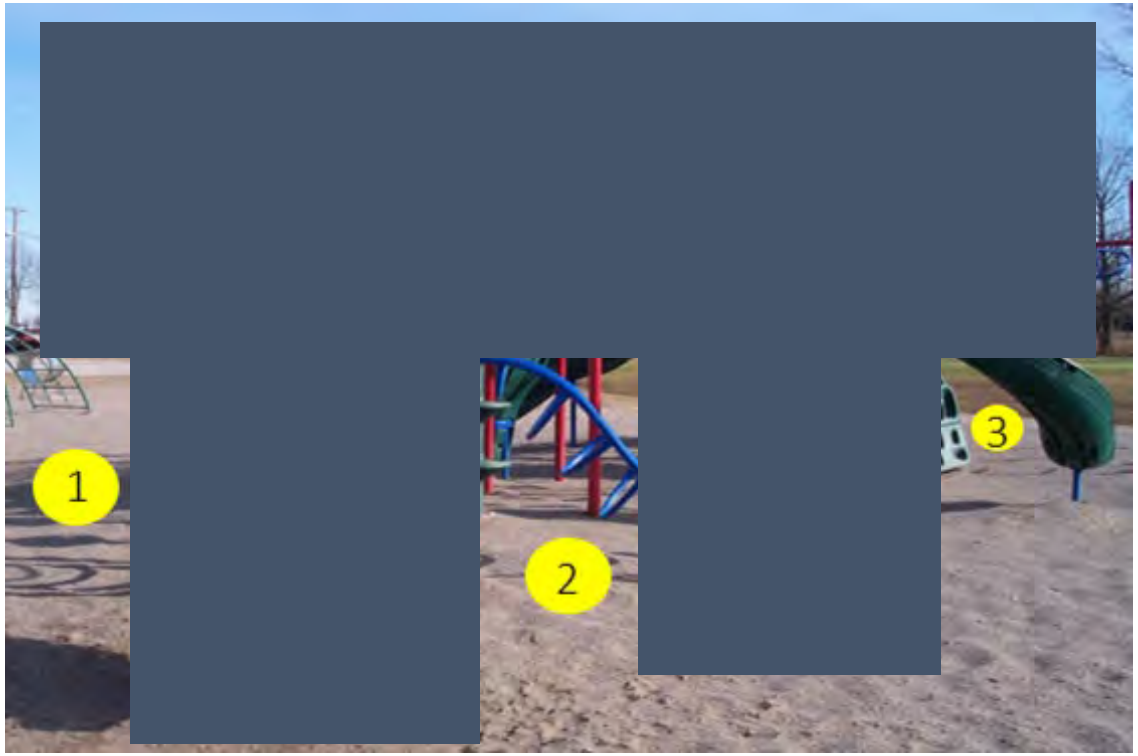
Test Plan Protocol



The impact attenuation test sites were identified by the sites expected to have the least impact attenuation surfacing materials as specified in *ASTM F1292 -13 Section 16.2.2.* Procedures included testing a minimum of three different impact test sites in the use zone of each play structure (*ASTM F1292-13*, *Section 16.1*). If there were more than one type of installed playground surface around the selected structure(s), the procedure included testing on **each** type of installed playground surface at **a minimum of three test sites** (*ASTM F1292-13*, *Section 16.2*)

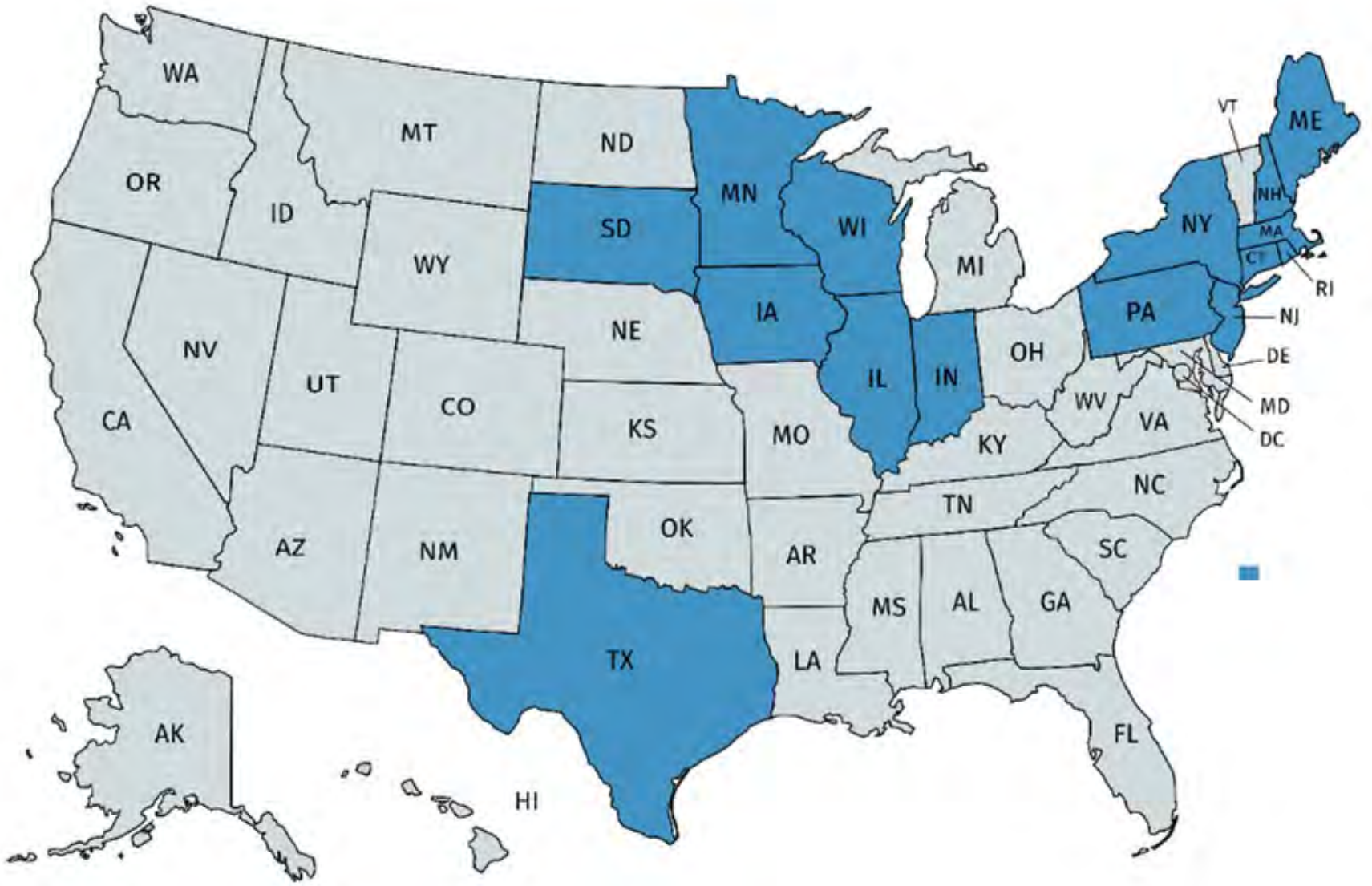
Deliverable #4

Completion of on-site surface impact attenuation testing

- Validated instrument
- Pilot tested the test plan procedures
- Test and evaluated first year 103 public playgrounds
- The first 100 completed were considered 100 of the 400 goal to allow for efficient use of project resources.
- Playgrounds proximal to one another could be completed during the same travel time / trip.

It is important to note that this non-random sampling of the first 100 cases limits generalizability of the findings both in terms of statistical power (small number of cases) and generalizability. All findings summarized here should be considered preliminary and should not be considered a statistically representative sample of playgrounds in the US.

- 103 playground sites
  - 15,349 miles driven
  - 3,687 drops performed
  - 3,130 photos taken
- 15 States
  - Connecticut (n = 4)
  - Illinois (n = 26)
  - Indiana (n = 6)
  - Iowa (n = 5)
  - Maine (n = 2)
  - Massachusetts (n = 4)
  - Minnesota (n = 19)
  - New Hampshire (n = 1)
  - New Jersey (n = 3)
  - New York (n = 6)
  - Pennsylvania (n = 5)
  - Rhode Island (n = 4)
  - South Dakota (n = 3)
  - Texas (n =2)
  - Wisconsin (n = 13)



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Data Analysis

- There were multiple ways to analyze the data
- It is important to note the perspective from which the data is being analyzed
- Statistical analysis
  - Quantitative Analysis
  - Qualitative Analysis

Field Testing Procedures

- The number of structures that were involved with drop tests per playground ranged from 1 structure to 14 structures.
  - The majority of playgrounds tested (88%) had two or more structures.
  - A few playgrounds (n=12) contained only one equipment structure with one surface material in its use zone. In these cases, nine impact (drops) were conducted in the use zone of each play structure.

What Type of Surface Material was Present?

- Most public playgrounds have loose-fill materials (95%).
- Wood products are the most widely used type of loose-fill materials (85%).
- Most playground structures have suitable surfacing under and around playground equipment (90%).

Surfacing Material Single surface	Frequency (Public School)	Percent (Public School)	Frequency (Public Park)	Percent (Public Park)
Particular rubber	0	0	2	2.9
Pea gravel	1	3	8	11.4
Poured-in-place	2	6.1	1	1.4
Rubber tiles	2	6.1	0	0
Sand	2	6.1	7	10
Wood product	18	54.5	40	57.1
Surfacing Material **Multiple surfaces**	**Frequency (Public School)**	**Percent (Public School)**	**Frequency (Public Park)**	**Percent (Public Park)**
Pea gravel, Other surfacing materials, Grass	2	6.1	1	1.4
Sand, Pea gravel, Other surfacing materials	0	0	1	1.4
Sand, Pea gravel, Wood product, Poured-in-place, Grass, Dirt, Concrete	0	0	1	1.4
Sand, Poured-in-place	0	0	1	1.4
Sand, Wood product, Other surfacing materials	0	0	1	1.4
Sand, Wood product, Poured-in-place, Concrete	0	0	1	1.4
Wood product, Dirt	0	0	1	1.4
Wood product, Grass	2	6.1	0	0
Wood product, Grass, Dirt	1	3	0	0
Total	**33**	**100.0**	**70**	**100.0**

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Inappropriate Surfacing

8 out of the 103 playgrounds had one or more surfaces that were inappropriate to perform the impact attenuation tests.

Inappropriate surfacing to test

Playground Surfacing Impact Attenuation Results

There were 415 play structures assessed

- 27 play structures were found to have an inappropriate surface material under and around the play structure.
- 87% of play structures fell below 200 *g*'s.
- 81% had a HIC score below 1000 at all three test sites surrounding each play structure.

	***g*-max # Sites Below 200g**				**HIC # Sites Below 1000**			
	3	**2**	**1**	**0**	**3**	**2**	**1**	**0**
All Structures (n=415)	360 (87%)	16 (4%)	5 (1%)	34 (8%)	*338 (81%)*	*29 (7%)*	*9 (2%)*	*39 (9%)*

*NOTE: Surfaces classified as "inappropriate surfaces" by field testers were categorized in the zero test sites column (judgement that all three test sites would exceed performance criterion).

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Playground Surfacing Impact Attenuation Results

- 93% of tested surface material (n=388) under and around tested play structures are meeting impact attenuation standards of <200 *g*
- 87% had a HIC score below 1000 at all three test sites surrounding each play structure.

	***g* -max # Sites Below 200g**				**HIC # Sites Below 1000**			
	3	**2**	**1**	**0**	**3**	**2**	**1**	**0**
All Structures (n=388)	360 (93%)	16 (4%)	5 (1%)	7 (2%)	*338 (87%)*	*29 (7%)*	*9 (2%)*	*12 (3%)*

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Playground Surfacing Impact Attenuation Results Public School and Public Park

	***g*-max** # Sites Below 200g				**HIC** # Sites Below 1000			
	3	**2**	**1**	**0**	**3**	**2**	**1**	**0**
Public School (n=124)	119 (96%)	2 (2%)	1 (1%)	2 (2%)	*112 (90%)*	*6 (5%)*	*2 (2%)*	*4 (3%)*
Public Park (n=264)	241 (91%)	14 (5%)	4 (2%)	5 (2%)	*226 (86%)*	*23 (9%)*	*7 (3%)*	*8 (3%)*
TOTAL (n=388)								

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Playground Surfacing Impact Attenuation Results
A Variety of Playground Surface Types

	***g* -max** # Sites Below 200g				**HIC** # Sites Below 1000			
	3	**2**	**1**	**0**	**3**	**2**	**1**	**0**
Sand (n=34)	29 (85%)	3 (9%)	2 (6%)	0 (0%)	*28 (82%)*	*3 (9%)*	*2 (6%)*	*1 (3%)*
Pea Gravel (n=40)	32 (80%)	5 (13%)	1 (3%)	2 (5%)	*26 (65%)*	*7 (18%)*	*4 (10%)*	*3 (8%)*
Particular Rubber/Crumb Rubber (n=1)	1 (100%)	0 (0%)	0 (0%)	0 (0%)	*1 (100%)*	*0 (0%)*	*0 (0%)*	*0 (0%)*
Wood Chips (n=126)	122 (97%)	4 (3%)	0 (0%)	0 (0%)	*114 (90%)*	*12 (10%)*	*0 (0%)*	*0 (0%)*
Wood Mulch (n=7)	7 (100%)	0 (0%)	0 (0%)	0 (0%)	*7 (100%)*	*0 (0%)*	*0 (0%)*	*0 (0%)*
Engineered Wood Fiber (n=132)	130 (98%)	1 (1%)	0 (0%)	1 (1%)	*127 (96%)*	*3 (2%)*	*1 (1%)*	*1 (1%)*
Unknown Wood (n=0)	0	0	0	0	*0%*	*0%*	*0%*	*0%*
Rubber Tile (n=12)	12 (100%)	0 (0%)	0 (0%)	0 (0%)	*11 (92%)*	*0 (0%)*	*0 (0%)*	*1 (8%)*
Poured-in-Place (n=34)	27 (79%)	1 (3%)	2 (6%)	4 (12%)	*24 (71%)*	*2 (6%)*	*2 (6%)*	*6 (18%)*
Synthetic Grass (n=0)	0	0	0	0	*0%*	*0%*	*0%*	*0%*
Other (n=2)	0 (0%)	2 (100%)	0 (0%)	0 (0%)	*0 (0%)*	*2 (100%)*	*0 (0%)*	*0 (0%)*
TOTAL (n=388)								

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Drop Height

Impact attenuation performance changed when structures were at the 9-12 foot range (sharp 9% decrease) by g-max and a 36% change by HIC. Structures less than 3 feet in height met impact attenuation criteria at all three test sites (99%). The majority of up to 6 feet in height (95%) met criteria at all three test sites.

	***g*-max** # Sites Below 200g				**HIC** # Sites Below 1000			
	3	**2**	**1**	**0**	**3**	**2**	**1**	**0**
0-3 feet (n=72)	71 (99%)	1 (1%)	0 (0%)	0 (0%)	*71 (99%)*	*1 (1%)*	*0 (0%)*	*0 (0%)*
>3-6 feet (n=88)	84 (95%)	2 (2%)	1 (1%)	1 (1%)	*81 (92%)*	*4 (5%)*	*1 (1%)*	*2 (2%)*
>6-9 feet (n=203)	185 (91%)	11 (5%)	2 (1%)	5 (2%)	*174 (86%)*	*15 (7%)*	*6 (3%)*	*8 (4%)*
>9-12 feet (n=22)	18 (82%)	2 (9%)	2 (9%)	0 (0%)	*11 (50%)*	*9 (41%)*	*1 (5%)*	*1 (5%)*
12+ feet (n=3)	2 (67%)	0 (0%)	0 (0%)	1 (33%)	*1 (33%)*	*0 (0%)*	*1 (33%)*	*1 (33%)*
TOTAL (n=388)								

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Playground Surfacing Impact Attenuation Results
Fall Height and Different Types of Surface Materials

Fall Height	Sand (n=306)	Pea Gravel (n=351)	Wood Chips (n=1131)	Wood Mulch (n=63)	Engineered Wood Fiber (n=1188)	Rubber Tile (n=108)	Poured-in-place (n=306)
0-3 ft	63 (100%)	63 (100%)	204 (99%)	--	198 (100%)	9 (100%)	108 (100%)
3-6 ft	27 (100%)	60 (95%)	261 (100%)	18 (100%)	304 (99%)	18 (100%)	63 (70%)
6-9 ft	166 (88%)	123 (80%)	567 (97%)	36 (100%)	633 (98%)	72 (89%)	63 (58%)
9-12 ft	20 (74%)	35 (65%)	67 (83%)	9 (100%)	27 (100%)	--	--
12+ ft	--	9 (50%)	--	--	3 (33%)	--	--
Total Test Locations < 1000 HIC	**276 (90%)**	**290 (83%)**	**1099 (97%)**	**63 (100%)**	**1099 (98%)**	**99 (92%)**	**234 (76%)**

Loose fill products experienced a sharp decrease in impact attenuation compliance at heights above 9 ft., while unitary products experienced a sharp decrease in performance at heights above 6 ft.

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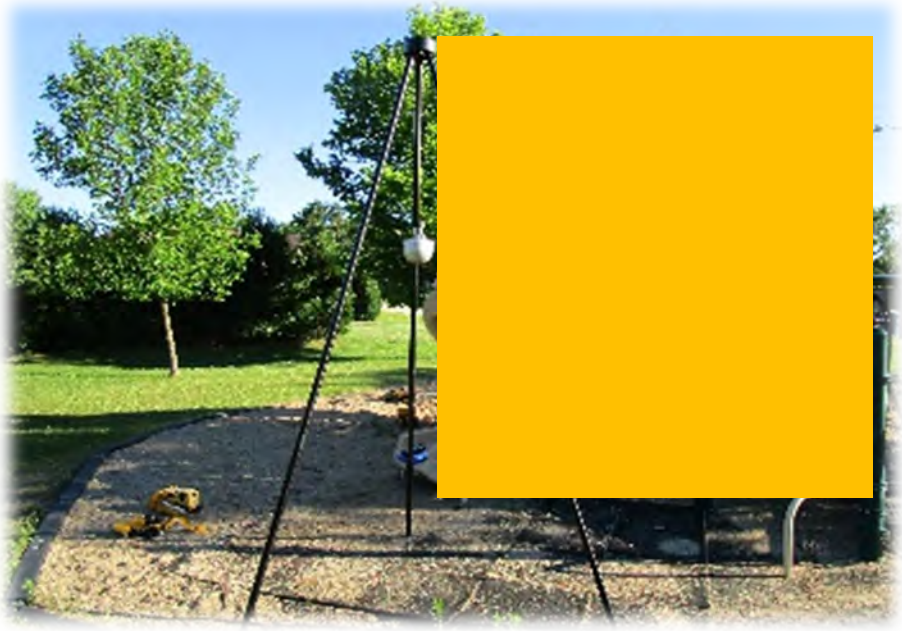
Rubber Mats (Kickmats)

- Rubber mats (17.5%) are being installed under heavy use equipment (i.e swings and slide exits).
- Installation: Below and Above Loose Fill Surface Material
- Both schools and parks utilize rubber mats under heavy use equipment.



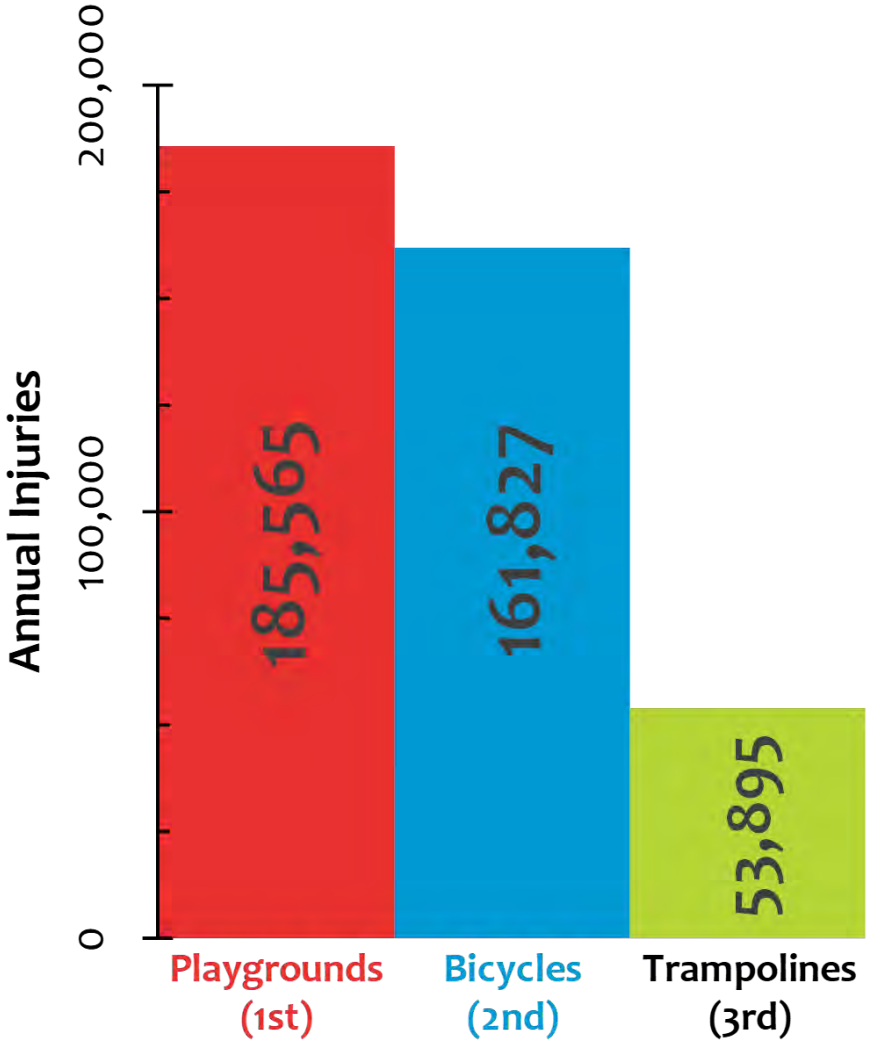
Recommendations for Future F08.63 Discussion

The project tested to the standard. Field testing challenges and recommendations:

- Review definitions of drop height, critical fall height, fall height
- Review the selection of a test site
- Validate 3 impact attenuation drops per test site
- Validate rationale for averaging drops 2 & 3
- Document and report environmental conditions
- Sub-layer materials for documentation of field testing
- Remove tamping procedures from field testing procedures
- Review the purpose of the photos in F1292
- Elevated structures less than 18 inches to be considered to be excluded from field testing
- Remove critical fall height for field-testing
- Establish drop height for field-testing
- Interpret and report results from field testing
- Data can be evaluated to provide insight to minimum impact attenuation performance
- Procedures and instrument for ambient and surface temperature measure

The Problem: Playground Injuries Remain Stagnant

- Each year in the United States, over 200,000 children are injured on playgrounds seriously enough to seek emergency room treatment (Hanway 2016; Tuckel et al. 2017).
- Upper extremity and head and neck injuries are a concern. Fractures of an upper limb account for approximately half of medically treated injuries, while head and neck injuries account for one third of all injuries (Adelson et al. 2018; Tuckel et al. 2017; Loder 2008).
- Annually 20,000 children visit U.S. emergency departments for traumatic brain injuries on playgrounds (Cheng et al. 2016).



(Schwebel & Brezausek 2014)

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Are Traditional Playground Standards Comprehensive Enough?

There is a need for more innovation related to risk assessment within current standards, which will advance the safety performance of installed playground surfacing materials. *For example, testing for head injury is insufficient if upper extremity fractures are more common!*

Field testing to examine the safety of playgrounds and obtain data on impact attenuation is important. Procedures, processes, and protocols should be at the forefront of standards. Laboratory based standards do not directly translate to field testing methodology.

There is a need for innovative technologies and metrics, related to environmental factors. *Envexposures present the potential for long-term or chronic health problems that may not present themselves until significantly later in life.*

Thoughtful (!) innovation is needed to promote safe, active child play!

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References

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