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ABSTRACT

Noting that 90 percent of serious playground injuries result from falls to hard surfaces, this paper reviews the advantages and disadvantages of various playground surfacing materials in terms of cost, climate, durability, aesthetics, and play value. Findings are based on the personal experience of the author, government documents, laboratory tests, manufacturers' literature, and interviews with playground equipment and surfacing manufacturers, as well as school and park maintenance personnel. The report lists findings of a previous comparative study of surfacing materials including commercial, loose organic, loose inorganic, and other loose materials. In a discussion of installation issues, the report suggests that recycled plastic timbers are easier to install than wood or concrete. Noting the special concerns of buyers in extremely cold and hot climates, the report examines weather effects on surfacing. In an examination of cost considerations, the report suggests that the safety benefits of unitary surfacing may outweigh its initial relatively high cost. A discussion of impact attenuation of various surfaces concludes that no single surfacing material is best for all conditions and warns buyers to consider carefully issues such as manufacturer reputation and laboratory test results before buying. (Contains 11 references.) (AJH)

PROTECTIVE SURFACING FOR PLAYGROUNDS*

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The purpose of this paper is to review the advantages and disadvantages of various types of playground surfacing materials with respect to safety, cost, climate, durability, aesthetics, and play value. The information is taken from the personal experience of the author, various government documents, laboratory tests, manufacturer's literature, interviews with leading playground equipment and/or surfacing manufacturers, and interviews with school and park maintenance personnel in various geographical areas.

The Consumer Product Safety Commission (CPSC, 1981) concluded that falling from playground equipment onto hard surfaces accounts for about 70 per cent of all playground injuries. Most of these injuries result from falling onto hard ground surfaces such as concrete, asphalt and hard-packed earth and a small percentage result from falling from one part of the equipment onto other parts of the equipment. However, 90 per cent of serious injuries result from falls to hard surfaces (Tinsworth & Kramer, 1990). These data are consistent with data from litigation (lawsuits) by Frost and Sweeney (1996). Consequently, the most expedient means of protecting children from injuries in falls on playgrounds is to install and maintain resilient surfacing under and around playground equipment as recommended by the CPSC (1991; 1994) and the American Society for Testing and Materials (1991).

Leading recreation authorities have recommended that resilient surfaces be installed under playground climbing apparatus since the early 1900's (Butler, 1952) but little was accomplished until the early 1980's. Extensive scientific studies to evaluate the effectiveness of various types of playground surfacing materials have not been done on real playgrounds but a growing number of laboratory tests are being conducted.

Early experiences of the Los Angeles School System provide some indication of the effectiveness of resilient surfacing in reducing injuries and fatalities. Between 1931 and 1951 the School System recorded 11 playground deaths from falls onto hard surfaces on playgrounds (Butwinick, 1974). In a single school year of 180 school days "... one child in every 225 had suffered a serious injury - a fractured skull, a shattered leg, a dislocated shoulder or a broken arm" (Brashear, 1952).

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Following a series of committee investigations, the School System installed rubber surfacing under playground equipment. No additional fatalities were recorded during the next decade and the incidence of fractures and concussions was reduced from 1.25 per school in 1951 to 0.47 in 1965 (Butwinick, 1974). This was one of the first large-scale accounts (largely anecdotal) concluding that resilient surfacing works in preventing playground injuries and fatalities.

The L. A. School District experience included experimental installations of various surfacing materials, beginning around 1950 (CPSC, 1978). Based on their experience, specifications for protective surfacing were developed. These required a cushioning material that: (1) provides adequate protection <u>at all times</u> under <u>any conceivable weather conditions</u>, (2) continues to provide adequate protection after <u>extended and continuous actual service</u> without excessive need for maintenance and repairs, and (3) provides adequate protection <u>without introducing any additional hazards or dangers.</u>

The L. A. School District found that hard surfacing materials such as asphalt did not require excessive repair but did not offer protection from injuries in falls. Soft surfacing materials such as sand, pea gravel, bark, and wood or rubber mulch required continuous maintenance to be an effective cushioning material but they introduced new hazards such as concealment of glass or other sharp objects and animal feces and microorganisms. Consequently, the District opted to specify protective surface cushioning mats for installation under playground equipment.

Early data from the National Electronic Injury Surveillance System, instituted in 1972, revealed an unacceptable number of injuries to children and the CPSC developed national playground safety guidelines (CPSC, 1981; revised, 1991, 1994). Impact tests were conducted on several types of resilient surfacing materials; loose organic materials, loose inorganic materials and commercial materials. Advantages and disadvantages of each type are identified.

LOOSE ORGANIC MATERIALS (bark nuggets, mulch, coco shell mulch, and shredded wood)

<u>Advantages</u>:

. aestheticaly pleasing appearance
. not carried into buildings as readily as inorganic loose materials.
. inexpensive in many areas (very expensive in some)
. some types support wheel chair traffic

<u>Disadvantages</u>:

- decomposes over time
- will freeze
- resilience affected by rain and humidity
- may allow growth of microorganisms
- may harbor sharp materials and insects
- may lose cushioning properties as dirt and other materials mix
- wind may blow material
- subject to burning
- requires regular maintenance

INORGANIC LOOSE MATERIALS (sand, pea gravel)

Advantages:
- sand is an excellent play material (pea gravel is not)
- inexpensive in most areas

Disadvantages:
- wind may blow sand
- pea gravel may be lodged in ears and nose and swallowed
- pea gravel may be thrown in eyes
- may become compacted
- may harbor sharp materials and insects
- may lose cushioning properties as dirt and other materials mix
- sand freezes (pea gravel resistant to freezing)
- pea gravel difficult to walk on
- wheel chairs will not roll on these materials
- may create slippery areas on adjacent walks and tricycle tracks
- require constant maintenance
- pea gravel lacks aesthetic qualities

OTHER LOOSE MATERIALS (chopped or shredded rubber, recycled materials)

Advantages:
- not amenable to blowing in the wind
- may support wheel chairs (shredded material)
- costs less than unitary materials (more than sand and pea gravel)
- not likely to harbor mold and insects

Disadvantages:
- may be flammable (may be treated with flame retardant)
- may stop up drains
- may cause choking (chopped rubber particles)
- may contain toxic material or sharp objects (recycled tires)
- drains readily with proper installation

COMMERCIAL MATERIALS (mats, poured surfaces)

Advantages: ("may" is used because specifications of material vary widely from manufacturer to manufacturer)

. may be very durable
. easy to keep clean
. not amenable to hidden sharp objects
. not likely to harbor insects
. when properly installed, maintenance is low
. predictable resiliency qualities
. will support wheel chair traffic
. may be made from recycled materials
. may drain freely
. may resist freezing (depending on type and installation)
. may be aesthetically pleasing
. poured material is seamless

Disadvantages:

. subject to vandalism
. corners and edges of mats subject to coming loose
. must be used on compact surfaces (asphalt, concrete, packed aggregate)
. may be flammable
. may include toxic materials
. quality and specifications (advantages) vary widely among types
. is expensive

INSTALLATION

Loose materials are typically installed within 12 inch high retaining borders constructed of plastic, wood or concrete. Recycled plastic timbers are available from playground equipment manufacturers. They are more resilient than wood or concrete (safer), easy to install and may be readily relocated. They are more expensive (about $40 to $60 for each 4 inch or 5 inch X 12 inch x 6 feet timber with stakes) than the least expensive wood timbers. Cost of materials is about $6.50 to $10 per linear foot plus installation. Installation is simple and inexpensive, requiring (on level surfaces) that steel stakes simply be driven through the existing holes in the timbers into the ground. Rock near the surface would complicate the installation.

Some complaints have been heard regarding shifting of plastic timbers in loose or wet soils and children removing the timbers (e. g., in Alaska). It appears that type of ground (e.g., sand, clay, marsh, rock) should be taken into account in determining whether timbers will remain stationary. In some areas, timbers are partially submerged in base ground to ensure stability. This may require special attention to underground drainage to prevent standing water. The plastic timbers provide good seating areas for children and they are more forgiving when children fall into them.

Pressure treated wood timbers are inexpensive (about $3 for a 4 1/2 inch wide X 8 feet long timber) and durable. Since 4 1/2 inch wide timbers are stacked three high, the per foot cost of materials (plus re-bar, spikes, and installation) is about $1 to $1.25 per linear foot. The CPSC (Tyrrell, 1990) assessed the cancer risk to children playing on wood treated with chromated copper arsenate (CCA), a chemical commonly used in landscape timbers and lumber used in playground equipment. They concluded that the risk of skin cancer ranged from <1 in a million ("negligible") to 8-9 in a million ("possible hazard"). Some installers cap timber borders with naturally rot resistant, 2 inch dimension lumber (e.g., redwood) to prevent contact of skin with timbers.

If properly installed, little maintenance is required for either plastic or wood timbers. Timbers of larger dimensions, e.g., 6 inch X 6 inch X 8 feet, and stacked two high, are more expensive than smaller dimension wood timbers but they create a better appearance, a more sturdy border and provide good seating areas for children. All corners should be rounded. Wood timbers are usually installed by driving re-bar through drilled holes in the timbers deeply into the ground and adding spikes as needed. Two inch dimension lumber fitted over the top as a finish plate can conceal the ends of re-bar and provide a more finished product (e.g., fewer splinters) for sitting.

Concrete is often used for public park and public school safety surface borders. The major advantage is ease of maintenance. Although no major pattern of injuries on safety surface borders is known to the author, concrete is harder than wood or plastic and does increase the potential for injuries in falls. If used for borders, concrete edges should be rounded and smooth. Like plastic and wood, concrete borders can also be used as seating surfaces.

Installing safety surface borders should be done be experienced installers. The top of the borders should be level for loose surface materials flow down-hill when disturbed by children playing - like water except more slowly. Provisions must be made for drainage to ensure that water falling into the loose surface area flows through the borders and away from the area. In wet areas, special gravel beds may be needed under the resilient surface material to assist in drainage. Permeable membranes are used between loose surfacing material and below grade drainage material to prevent mixing of the two types of material.

The typical recommended initial depth of loose material is 12 inches of complete infill within the 12 inch high borders. The material should not be allowed to fall below 8 inches in depth before replenishing. Some loose materials are commercially prepared and installed with special drainage systems. They support wheel chair traffic and may be installed by volunteers if they are given proper directions.

Commercial unitary surfacing materials, e.g., mats and poured surfaces should be installed only by trained, experienced installers selected by the manufacturer of the surfacing. The installation of this surfacing material and the manufacture of the material are highly technical tasks, requiring laboratory tests and on-site experience. The prospective purchaser should check references and laboratory test results (including the reputation of the laboratory), visit previous installations, require long-term warranties, determine extent of experience, and select very strict specifications for bidding the product.

The writer has seen examples of inferior materials breaking up within weeks of installation and of compacted support surfaces eroding, allowing the unitary material to disintegrate. Concrete and asphalt bases appear to perform well. Given proper manufacture and installation, unitary materials can provide excellent, long-term protective playground surfaces.

WEATHER EFFECTS

The purchaser should check closely with the manufacturer to determine whether the surfacing under consideration is appropriate for their region. My associates in Canada and Alaska contend, and I have seen first hand, that sand freezes solid in extreme cold while pea gravel tends to resist freezing (less water absorption). Even when some freezing occurs in pea gravel, children's movement may break up the frozen area and increase the resiliency. They also claim that wood mulch is subject to freezing and in wet areas is inclined to mold and harbor spores. Among the loose materials, it appears that pea gravel is the only type that may provide reasonably safe play surfaces in extreme cold. When one must weigh this advantage against the disadvantages of pea gravel having poor play qualities and subject to being placed in noses and ears of young children, the choice is clear. Far more children are injured from falling onto hard surfaces than from all incidents involving pea gravel.

The other extreme, heat, must also be considered in selecting resilient surfacing materials for playgrounds. Sand and pea gravel get hot enough to be uncomfortable to bare skin but are not likely to cause severe burns. Wood mulch remains relatively comfortable for skin contact. Manufactured surfacing materials vary widely in composition and quality across manufacturers so temperature factors should be carefully explored before purchasing. Companies with extensive experience and success in many geographical areas contend that use of their materials has not resulted in burns to children requiring medical treatment. The author is aware of only one law-suit resulting from a burn injury from contact with unitary surfacing in a play area. This was several years ago and involved an early type of non-porous surfacing material, black in color.

A leading manufacturer that installs over 500 projects annually nationwide recommends that unitary materials be tested for fall heights at extreme temperatures ranging from sub-freezing (30 degrees) to normal range (72 degrees) to very hot (120 degrees). Products tend to get harder at colder temperatures. They should be installed in above 40 degree temperatures and asphalt should not be used for curbing or base in cold climates. This manufacturer contends that any type of synthetic surface gets about 20 degrees hotter than the outside temperature or about 20 to 30 degrees cooler than asphalt. Red, blue, green, tan, black colors are recommended over egg shell, gray, pink, and teale. Basically, the primary colors are best for UV resistance. The leading unitary materials are porous, reducing non-play time and eliminating standing water. They are slip resistant when wet and may have a poured cap that is more UV resistant and less likely to burn skin than the material used in the base.

COST OF SURFACING MATERIALS

Organic and inorganic loose surfacing materials are the least expensive, ranging from about .50 to $1.00 per square foot (12 inches deep). Sand and pea gravel are sold by the cubic yard or ton and wood chips are sold by the cubic yard. Prices vary with location, availability, distance to be hauled and type of material. The initial cost of manufactured, loose, recycled surfacing materials falls between that of loose organic and inorganic materials and manufactured unitary materials, ranging from about $3.50 to $4.50 per square foot for regular material to about $7.00 to $8.00 per square foot for materials treated with flame retardant. Initial cost varies with type of material, freight costs (distance from factory), etc. The initial cost of manufactured unitary surfacing materials is quite high, ranging from about $10 to $18.00 a square foot depending on depth, color combinations, base material, location, etc.

Great care should be exercised in selecting and installing surfacing materials. If the entire operation is placed in the hands of experienced installers linked to reputable manufacturers who certify that ASTM, CPSC and manufactujrer's guidelines/standards are met, the playground sponsor has reasonable assurance of high quality. On the other hand, if the playground sponsor elects to use loose organic and inorganic materials, an experienced playground builder should inspect the sand, pea gravel or wood mulch before it is purchased and hauled to the site. There are possibilities of inferior quality materials, toxic materials mixed with loose materials, improperly sized materials, materials mixed with dirt, insect or mold infested materials, etc., that must be considered in selecting playground surfacing materials.

Assuming proper installation, manufactured unitary materials require less maintenance than the other types. Over time regular maintenance of loose materials reduces the cost difference. The maintenance factor alone is seen by many as sufficient reason to pay the extra initial price, especially in very high use playgrounds such as found in public schools and public parks. Coupled with the knowledge that very few playground sponsors maintain loose surfacing materials properly, the dependability of unitary surfacing to protect children in falls is a second compelling reason for promoting it's use. The safety benefits may well outweigh the initial cost differences.

IMPACT ATTENUATION OF PLAYGROUND SURFACE SYSTEMS

The CPSC (1990) published the results of extensive impact attenuation performance of various playground surfacing materials in 1990. The following year, the American Society for Testing and Materials conducted tests and published F-1292 - Standard Specification for Impact Attenuation of Surface Systems Under and Around Playground Equipment (1991). This specification establishes minimum impact attenuation requirements, based on scientific tests, for surface systems under playground equipment from which children may fall. The CPSC (1991) used the ASTM F-1292 specification in conducting tests of loose fill, playground surfacing materials. "Critical Height" for a surfacing material is defined as the maximum height from which an instrumented metal headform, upon impact, yields both a peak deceleration of no more than 200 G's and an HIC of no more than 1,000 when tested according the the procedure described in ASTM F-1292. Critical height is an approximation of the maximum fall height from which a life-threatening head injury would not be expected to occur.

Critical Heights (in feet) of Tested Materials

	Uncompressed depth			Compressed depth
Material	**6 in.**	**9 in.**	**12 in.**	**9 in.**
Wood mulch	7	10	11	10
Double Shredded Bark Mulch	6	10	11	7
Uniform Wood Chips	6	7	>12	6
Fine Sand	5	5	9	5
Coarse Sand	5	5	6	4
Fine Gravel	6	7	10	6
Medium Gravel	5	5	6	5

Although results are stated for "uncompressed depths" it is not realistic to assume that any of these materials will remain "uncompressed" following children's play on them. The "compressed depth" column is the more realistic guide in determining degree of protection.

The above tests by CPSC did not include manufactured materials for such products vary widely in composition and quality across manufacturers. Laboratory tests must be requested from the manufacturer. The leading manufacturers contract with ASTM testing approved or equivalent (reputable) laboratories to test their materials. Tests are typically conducted at different material depths - commercial loose materials at 4 inches, 6 inches and 8 inches; commercial unitary materials typically in 1 inch to 3 inch increments. Tests include varying drop heights in whole foot increments until the maximum allowed impact is reached (200 G's and 1,000 HIC). In addition to impact, tests are conducted for flammabiliy, permeability (water), friction, and temperature extremes (e.g., 30 deg., 72 deg., 120 deg.). Prospective purchasers should require and review these test results and confirm that they were conducted by reputable laboratories.

RECOMMENDATIONS

All of the above surfacing materials <u>may</u> be appropriate for playground use, depending on a range of variables. <u>No single surfacing material is best for all conditions</u>. Sand has the best play value; manufactured materials are the most durable and easy to maintain; hardwood chips are inexpensive in some areas, may be the most aesthetically pleasing, allow wheel chair traffic, and maintain resiliency well; pea gravel may best resist freezing in extreme cold or wet areas; sand and pea gravel are among the least expensive; shredded rubber (not chopped rubber), unitary materials and some wood products support wheel chair traffic.

The prospective purchaser must select materials very carefully, taking into account cost, anticipated use patterns, reputation of manufacturers and installers, manufacturer's insurance and warranty, and laboratory test results for impact resistance, flammability, permeability, friction (slip resistance) and resistance to freezing and heat. The buyer must avoid the common tendency to merely accept "lowest bids." Surfacing materials which look similar may differ dramatially in technical specifications and the supplier/installer may be unreliable and/or inexperienced. In do-it-yourself projects, using inexpensive loose materials, the buyer should see the material first-hand before delivery. Grades, purity and impact resistance of these materials vary widely from area to area. Finally, it serves no useful purpose to install resilient surfacing under and around playground equipment unless the sponsor also develops a detailed, regular maintenance program.

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