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Load Absorption Characteristics of Tyre Production Waste Rubber for Playground Floor Systems

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Abstract. The floor surfaces where slides and swings are placed in parks and playrooms should be soft and thick to ensure that whenever a child falls, the surface can withstand the impact and minimize injuries to the child. Shredded tyres from waste tyres or waste rubber from tyre manufacturing could become beneficial as shock absorber material which can be used as a playground floor. In this study, rubber cubes and rubber pads with 5%, 8% and 10% SBR mixes were prepared for mechanical testing. Two types of floor design surfaces with and without plywood on the surface were assembled for the shock test. G_{max} and HIC of this waste rubber flooring system were investigated using the compression test for the rubber cube and the drop test for the rubber pad. The criteria of general protection standards are 200g for optimum acceleration and 1000 for HIC. The G_{max} and HIC results indicated that the material and system could ensure a safe fall from up to 1.0m height.

1 Introduction

According to the Public Playground Safety Handbook [1], public playground equipment refers to equipment intended for use in the play areas of parks, schools, child care facilities, institutions, multiple family dwellings, restaurants, resorts, recreational developments and other areas of public use Playground safety is generally understood as the prevention of injuries. Test method specifications for impact attenuation of the surface under and around the playground equipment can be found in the ASTM F1292 standards and the European Standard series EN 1176 and EN 1177, covering playground equipment and surfacing [2]. The Malaysia Standard has developed safety standards for playground including the MS 966 Part 1 2001 Specifications for Material, MS 966 Part 2 2001 General Requirements and MS 966 Part 3 Test Methods [3].

Falls are classified as the most frequent root cause of serious playground injuries to children below the age of five years, with head injuries and fractures the most typical injuries. Head injury may vary from a bump on the head to severe brain injury. A US Consumer Product Safety Commission study found that 79% of equipment-related injuries involved playground falls, with 68% specifically involving falls towards the surface below the equipment [4].

Soft fall flooring that is of a natural substance works best. These include bark chips, grape mark, straw/hay, seaweed and leaf mulch. Shredded tyres from waste tyres or waste rubber from tyre manufacturing may possibly also be beneficial as shock absorber material that can be used as a playground floor [5].

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2 Methodology

Generally, these tiles are mostly made from waste rubber tyres, which have been bullet shaped, divided into two sizes (length: 0.1-3.0 mm and 3.1-7.0 mm) and then mixed with Styrene Butadiene Rubber. This research aims to find the load carrying capacity of factory waste rubber, to define suitable measurements of waste rubber chips and to design a flooring system that can make use of the waste rubber. The methodology used in this study was lab experiments. The experiments were conducted in the laboratory using lab equipment and data was collected from the test results.

2.1 Preliminaries Test

Preliminaries tests were used to design the cube and pad formwork. The designs of the cube, rubber pad casting and the design of mixes are as per Table 1 below.

Table 1: Cube and Pad Design Casting

Design	Cube		Pad		Pad+ Plywood	
	Rubber size					
SBR	(0.1-3.0) mm	(3.1-7.0) mm	(0.1-3.0) mm	(3.1-7.0) Mm	(0.1-3.0) mm	(3.1-7.0) mm
5%	3	3	1	1	1	1
8%	3	3	1	1	1	1
10%	3	3	1	1	1	1

2.2 Main Test

After preliminaries tests, the rubber cube and rubber pad were created in a Compression Test and Drop Test in the soil lab.

2.2.1 Compression Test

The apparatuses used for the compression tests were the compression test machine with a used load cell, strain dial gauge, compression dial gauge, cube rubber in three types of mixes as well as a camera. The apparatus for the compression tests were set up as in Figure 1. The compression tests were done until a cube strain of 12% was achieved from the height of the cube. Data from the test was collected in order to generate the analysis.

2.2.2 Drop Test

The apparatuses for the drop tests used such as a load cell, the Kyowa data Lodger, hemispherical headform with a 4.6kg load, supported pad rubber with three types of mixes and also a camera. The apparatus for the drop tests were set up as in Figure 2. To evaluate the dynamic responses of the rubber tile, four drop heights were tested i.e. 0.3 m, 0.6 m, 0.9m and 1.0m.

Fig. 1: Compression test set up

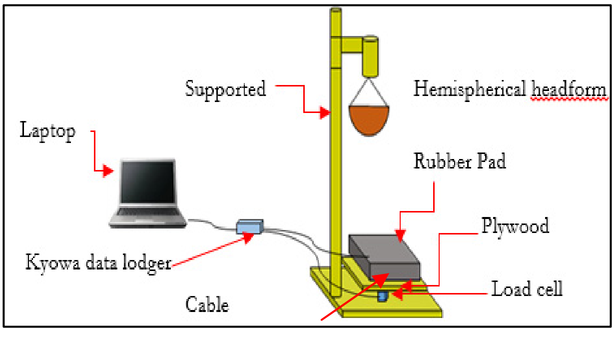

Fig. 2: Apparatus drop test set up

3 Result and Discussions

3.1 Compression Test

Table 2: Compression strength at 12 mm strain of rubber pad

Strain (mm)	Compression Strength at 12 mm (KPA)					
	5% (3.1-7.0)	8% (3.1-7.0)	10% (3.1-7.0)	5% (0.1-3.0)	8% (0.1-3.0)	10% (0.1-3.0)
12	21.70	24.43	24.80	24.43	27.90	32.98

Table 2 shows that the highest rubber cube strength is 32.90kpa for the 10% SBR mixed cube with 0.1mm until 3.0mm waste rubber sizes. The lowest strength of the rubber cube is 21.70kpa for the 5% SBR mixed cube with 3.1mm until 7.0mm waste rubber sizes.

The difference of strength of the cubes of 5% (0.1-3.0mm) and 5% (3.1-7.0mm) is 11.17%. The strength of the cube of 8% (0.1-3.0mm) is higher than that of the 8% (3.1-7.0mm) by 12.44%. The cube of 10% (0.1-3.0mm) has a higher strength than the cube of 10% (3.1-7.0mm) by 24.80%. It shows that waste rubber size 0.1mm until 3.0mm has the higher strength of compression. This can define the best size of waste rubber to be used as flooring absorption, which is 0.1mm until 3.0mm.

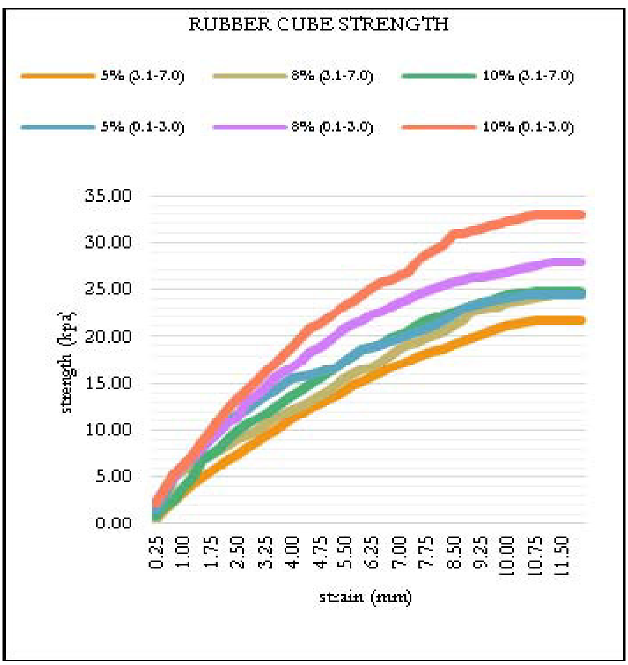

Fig. 3: Strength of six types of cube at 12% of strain

The strength value of the cube is affected by the SBR quantity as can be seen from Figure 3, which shows that the best mixed used is the 10% SBR quantity, rather than the 5% and 8% SBR quantity. As can be seen, the form of the curves is slight after 10mm until 12mm, showing that a rubber cube has reached the maximum of strength.

3.2 Drop Test

Figure 4 show the form of impact reaction on the rubber pad with plywood as a surface and also the rubber pad without plywood. It shows that when using the rubber pad with plywood as the surface or using plywood as playground flooring, the duration of the impact pulse is short, causing the peak deceleration and the corresponding force to be high. Therefore, the critical height is low, and the high deceleration caused by the short pulse may result in a serious head injury. It can be defined that the peak acceleration of waste rubber as playground flooring on the surface deforms upon impact, the time to bring the object to a pad is extended, the peak deceleration and corresponding force are reduced, the critical height is increased, and the likelihood of a life-threatening injury is decreased.

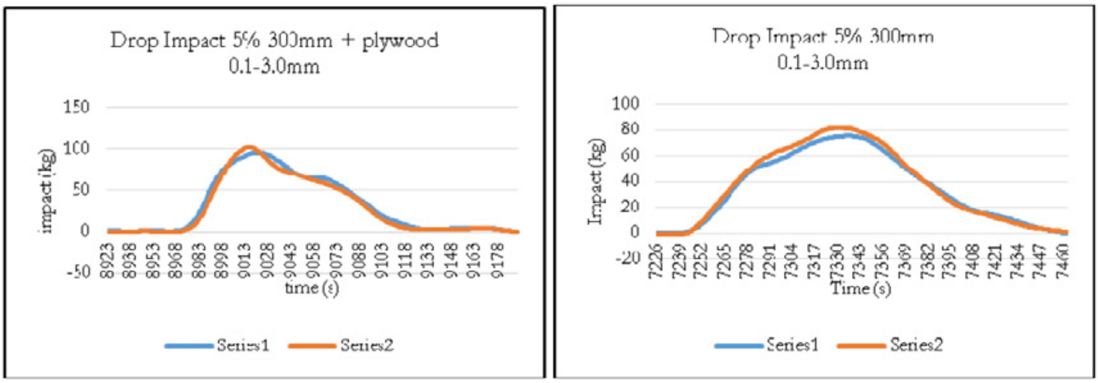

Fig. 4: Example graph of drop impact

Table 3: Peak Acceleration (G) value

Pad type	Deceleration(a @ g_{max})			
	300mm	600mm	900mm	1000mm
Plywood	52.2	67.2	99.2	95.1
5% (0.1-3.0)	34.1	56.4	68.9	74
5% (3.1-7.0)	35.6	54.2	71.5	73.6
8% (0.1-3.0)	35.0	59.7	61.6	80.0
8% (3.1-7.0)	34.6	56.4	73.4	71.1
10% (0.1-3.0)	34.8	51.1	74.1	72.8
10% (3.1-7.0)	34.5	54.5	74.6	75.5
5% (0.1-3.0)+plywood	43.2	57.5	72.2	84.4
5% (3.1-7.0)+plywood	44.4	63.5	80.5	71.9
8% (0.1-3.0)+plywood	42.1	61.5	79.7	94
8% (3.1-7.0)+plywood	39.5	54.7	65.8	85.6
10% (0.1-3.0)+plywood	49.8	69.9	72.2	75.5
10% (3.1-7.0)+plywood	42.6	63	81.1	80.2

Table 4: Head Injuries Criteria

Pad type	**HIC**			
	300mm	600mm	900mm	1000mm
Plywood	409	698	1216	1138
5% (0.1-3.0)	161	547	1243	1054
5% (3.1-7.0)	210	494	930	1082
8% (0.1-3.0)	165	538	634	1196
8% (3.1-7.0)	172	540	1250	898
10% (0.1-3.0)	175	414	1281	1087
10% (3.1-7.0)	201	482	1066	1061
5% (0.1-3.0)+plywood	329	568	943	1570
5% (3.1-7.0)+plywood	298	686	1456	1016
8% (0.1-3.0)+plywood	240	610	1377	1784
8% (3.1-7.0)+plywood	224	503	753	1539
10% (0.1-3.0)+plywood	393	854	850	989
10% (3.1-7.0)+plywood	277	725	988	1174

Based on Table 3, from the average of peak acceleration for the rubber pad, plywood, and rubber pad covered by plywood, the percent of distinction is defined. The difference between the peak acceleration (g_{max}) from using plywood and using the rubber pad is 18.71%, whilst the difference between using plywood with and without the rubber pad is 2.99%. The difference between using the rubber pad with and without a plywood cover is only 16.21%.

From table 4, the head injuries criteria shows that the best design of rubber pad as a flooring absorber is the rubber pad with waste rubber size 0.1mm until 3.0mm. The suitable quantity of Styrene Butadiene Rubber is 10% from waste rubber quantity. The HIC for the waste rubber pad with plywood as a flooring surface is much higher compared with only waste rubber pad. It can be defined that the waste rubber flooring is effective in reducing head injuries and it is also as suitable as playground flooring such as shredded rubber, wood chips, sand etc.

4 Conclusions

Waste rubber tiles are trusted to provide protective surfacing in playgrounds. It is essential that the selected tile provides the greatest shock-absorbing capability against head injury at a sustainable manufacturing cost. A comprehensive consideration of these two criteria in the selection of tiles will provide the maximum possibility to increase the chances of establishing safe, protective surfacing in playgrounds and reducing the occurrence of severe head injuries in kids. A waste rubber tile with 0.1mm until 3.0mm of waste rubber and using the rubber pad without plywood is seen as a suitable design for enhancing shock-absorption during a head impact. In this particular study, waste rubber flooring construction provided the cushioning effect which reduced the peak force to the head and delayed the occurrence of the peak value during impact, which markedly reduced the peak accelerations and HIC values.

Acknowledgement

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