SIMPLIFICATION AND TRANSFORMATION OF ASTM F1292-09 MEASUREMENT PROCEDURE FOR FALL ACCIDENT INJURY CRITERIA

Macky KATO[1], Yoshie SHIMODAIRA[2], Takeshi SATO[3] and Hiromi IIDA[4]

[1]*Waseda University, 2-579-15 Mikajima, Tokorozawa, Saitama 359-1192, Japan*
[2]*Nagano Prefectural College, 8-49-7 Miwa, Nagano, 380-8525, Japan*
[3]*Jissen Women's University, 4-1-1 Osakaue, Hino, Tokyo 191-8510, Japan*
[4] *Nihon Taiiku Sangyo Co., 2034 Kazama Nagano, 381-0023, Japan*

Accidents involving falls from playground equipment can be fatal for children. While it is necessary to protect children from such accidents, learning about the risk of falling is an essential aspect of playing with the equipment. Therefore, prevention of injuries resulting from falling is required. The risk of injury can be evaluated by means of the ASTM F1292-09 Head Injury Criterion (HIC) test. This test can be used to accurately quantify risk; however, the measurement procedure is complicated, and thus not easy to apply to many of existing equipment. ASTM F1292-09 requires simplification, even at a small cost of accuracy; for example, by reducing the number of trials. With this in mind, this study proposes a transformation equation to simplify ASTM F1292-09. Results of both HIC and G-max from the conventional procedure are in all cases more detailed than those from the simplified method. HIC and G-max values for both procedures linearly increase with fall height. It is therefore possible for the difference in outcomes between the regression equation of the conventional procedure and that of the simplified procedure to be added to the equation of simplified method as a transformation equation. This suggests that the combination of the simplified procedure and transformation equation would be equivalent to conventional ASTM F1292-09, with the advantage of being more easily and efficiently applied to the evaluation of existing playground equipment.

Introduction

More than 15,000 people are accidentally killed in Japan every year. The number of casualties through traffic accidents has been decreasing over the last decade. However, the number of casualties through accidents in daily life is greater than those caused by traffic accidents. One such "daily life" accident is falling. Statistic for 2011 show that 6,644 people were killed by traffic accidents, while 7,165 people were killed by accidents involving falls (MHLW 2012). Overall, the majority of victims of falls are elderly people, many of whom fall on flat places. However, younger people are more likely than elderly people to fall from structures, especially from playground equipment such as slides, climbing frames, and swings, and therefore require protection.

Once an accident involving playground equipment happens, caretakers often remove the equipment in order to prevent a fall accident again. However, this response is not always appropriate. Children need different types of experience while growing up. Awareness of the risk of fall accidents is most important in protecting them from hazardous situations. Even if they fall from the equipment, the materials on the ground should keep them safe. Ideally, all items of equipment should be evaluated in terms of safety. Therefore, the evaluation method should be easily applied because of the volumes of playground equipment.

HIC and G-max are used as criteria of injury risk. The evaluation methods for the two criteria for fall accidents are standardized in ASTM F1292-09. The ASTM F1292-09 evaluation method requires some preparation and three trials for each measurement. Because it takes a long time to measure, it is not practical to evaluate many existing items of playground equipment in a town. Thus, the shortened procedure should be adopted for mass evaluation, which would enable early removal of equipment with an associated risk of injury. In this study, the shortened procedure to evaluate injury risk of fall accident is suggested as a mass-evaluation method.

Method

A one-package device to measure HIC and G-max, shown in Figure 1, was developed for the evaluation of the impact attenuation of playground surfacing materials (Koitabashi 2006). There were five levels of fall height: 100, 150, 200, 250, and 300 cm. The impact surface at the measurement point was bare ground or sand. Depths of sand were at six levels: 6, 8, 10, 12, 14 and 16 cm. The conventional ASTM F1292-09 procedure was compared with the shortened procedure in this study using regression analysis. In the conventional procedure, the surface at the impact point must be hardened before the trials. Measurement of HIC and G-max are repeated three times and the average of the second and third value is recorded as the result of the trial. On the other hand, the shortened procedure needs just one measurement. Because the measurement value obtained by the shortened procedure would be smaller than that obtained by the conventional procedure, it must be appropriately transformed. The regression equation of G-max and fall height of the two procedures was compared. Differences between them were added to the measured value of shortened procedure. HIC was also processed in the same way as G-max.

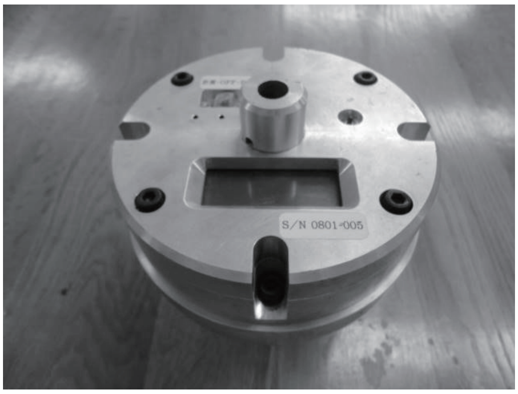

Figure 1 One-Package Equipment to evaluate impact attenuation (Koitabashi, 2006)

Result

Figure 2 shows samples of the acceleration and attenuation at the moment of impact. The surface at the impact point was bare ground. The heights were 100 cm and 150 cm. G-max at 100-cm height was 145, which was measured at point in 4.15 msec. G-max at 150-cm height was 214, which was measured at point in 3.025 msec. It exceeded the safety margin of G-max 200.

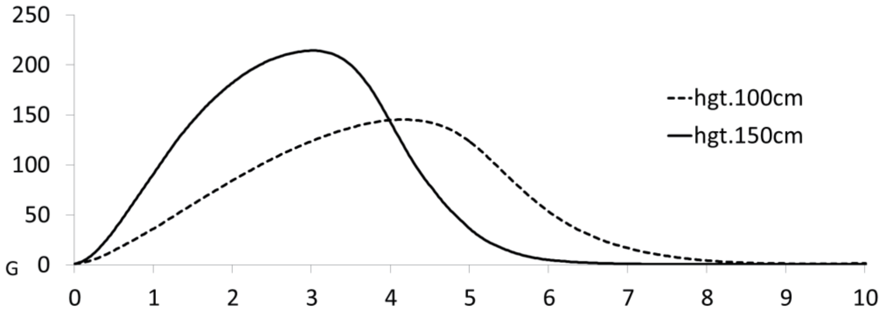

Figure 2 Sample of the variation of acceleration at the moment of impact

G-max for all conditions increased with height. It could be measured at an earlier point as the height increased (see Figure 2). Figure 3 shows the result of regression analysis of G-max by the conventional procedure and the shortened procedure. The measured value in both procedures increased with the height. The difference between measurements from the conventional and shortened procedures also increased with the height. This was true for all conditions of the sand. G-max decreased as the depth of the sand increased. The coefficients of the G-max regression equation also decreased as the depth of the sand increased.

Figure 4 shows the result of regression analysis of HIC by the conventional and shortened procedures. The variations of HIC show the same features as those of G-max. The difference between the two procedures increased with height, as in the case of G-max, and the coefficients of the HIC regression equation decreased as the height increased.

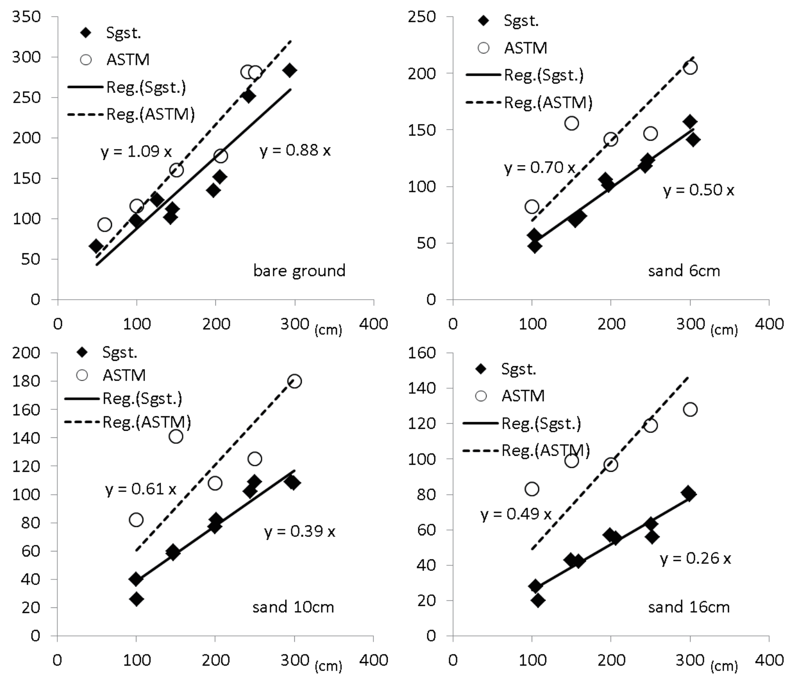

Figure 3 G-max and regression equation of bare ground and 16-cm depth of sand

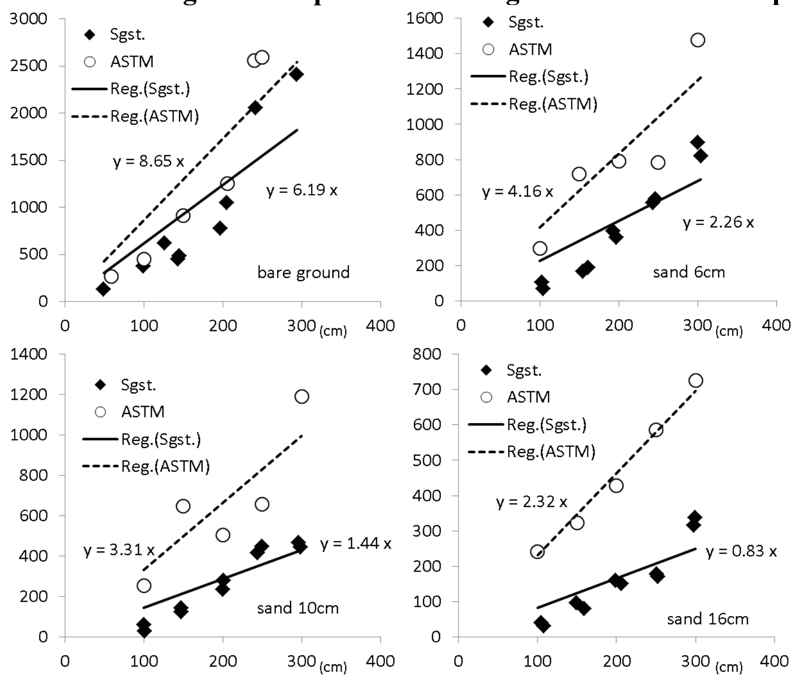

Figure 4 HIC and regression equation of bare ground and 16-cm depth of sand

Figure 5 shows the regression equation of the coefficient difference of G-max and HIC between the conventional and shortened procedures. The variation of the coefficient differences of G-max was unsteady. On the other hand, the coefficient differences of HIC decreased as the depth of sand increased.

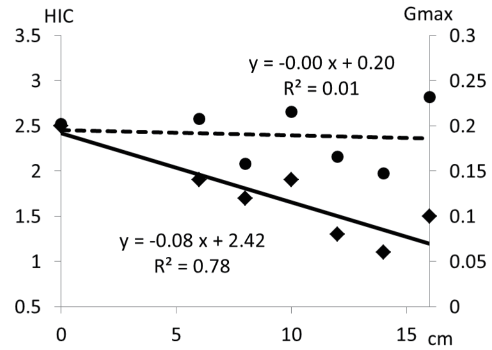

Figure 5 Coefficient differences of G-max and HIC between the conventional procedure and the shortened procedure

Discussion

As the results show, the G-max difference between the two procedures tends to depend on the height but not depth of sand. Acceleration and attenuation depend on maximum speed at the point of impact, and that speed is determined by the fall height, as can be observed in Figure 2. On the other hand, HIC difference tends to depend on both height and depth of sand. The evaluation value can be estimated by transformation of the shortened procedure measured value as follows:

G-max $e = x + 0.2h$
HIC $e = x + (0.08d+2.4)h$
x: measured value, h: fall height (cm), d: depth of sand (cm)

The reason for using "centimeter" is that the evaluation and transformation method should be applicable to practical use. "Centimeter" is normally used to measure depths and heights in Japan. Easy and familiar methods will be enable the investigators to efficiently research multiple items. The shortened procedure can be used to identify any dangerous objects that need improvements; however, it is not as appropriate for strict measurement as is conventional procedure. Therefore, measurement by means of the conventional procedure should be done to confirm initial identification of dangerous objects by the shortened procedure.

Acknowledgment

This study was supported by Japan Park Facilitate Association. We are pleasure to acknowledge the cooperation of the association and the students in Nagano Prefectural College.

References

ASTM (2009). ASTM F1292 - 09 Standard Specification for Impact Attenuation of Surfacing Materials within the Use Zone of Playground Equipment

Ministry of Health, Labour and Welfare (2012). Vital Statistics of Japan, Retrieved July 5, 2013, http://www.mhlw.go.jp/toukei/saikin/hw/jinkou/geppo/nengai11/dl/gaikyou23.pdf

Koitabashi, T., Kitazawa, S., Henmi, N., Yabuki, D., Hatakeyama, M. & Iida, H. (2006). Development of an One-Package Equipment for Evaluating the Impact Attenuation of Playground surfacing Materials. Research Reports of Nagano Prefecture General Industrial Technology Center, *1*, M41-M46.