SKID RESISTANCE OF SIDEWALK OF RESIDENCE AREA IN WET, SLUDGY AND SNOWY CONDITIONS

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ABSTRACT

Though many studies have been focused on skid resistance of roadways for vehicles safety, few studies have addressed on the skid resistance of sidewalks for pedestrians safety especially in winter. So, this study aimed to measure the skid resistance of the sidewalk in residence area to find out relationship between different surface types and skid resistance using British Pendulum Tester in a wet after snow-melting(here after we use the term snow-melting instead of wet after snow-melting), sludgy, and snowy conditions. The skid resistance was measured on surfaces including concrete interlocking block paving, colour asphalt pavement, granite block paving, manhole, and tactile paving for visually impaired. Five trials at each measurement were made to derive the average and standard deviation of British Pendulum Number (BPN). From this study, we suggested that the skid resistance of various surface types varied depending on the paving materials and weather conditions. Secondly, the appropriate level of consistency of skid resistance should be controlled along the pedestrian route. Thirdly, a careful consideration in placing manhole and paving for vision impaired should be made.

1. INTRODUCTION

Skid resistance is one of the important factors in assuring road safety at winter season. Though many studies have been focused on skid resistance of roadway for vehicles safety, few studies have addressed on the skid resistance of sidewalk for pedestrians safety especially in winter seasons. As referred by Berggård(2010), pedestrians slipping and falling is a major safety problem around the world, not least in countries with long winters such as Sweden where about 25000-30000 people need medical care every year for treatment of fall injuries. Owen (2000) gave an insight on the importance of slip resistance while we consider the vulnerability of the elderly. Thurmon, Jeffrey, and James (2002) referred that fall related accidents among older adults are due more to factors influencing compensation of a slip rather than gait characteristics influencing slip initiation. Though studies referred the risk of fall accidents and the vulnerability of older people, but few studies have addressed on the skid resistance of sidewalk. So, this study was motived by two questions including how much the skid resistance will be decreased by weather change in terms of snow-melting, sludgy, and snowy conditions and how much skid resistance will be varied along the pedestrian route. In South Korea, skid resistance of the sidewalk has not widely tackled, though the increase rate of the elderly are so fast. Though the criterion for the skid resistance of curbs within sidewalk was set as 40BPN in Installation and Management Guideline of Sidewalk in South Korea, the importance of skid resistance of sidewalk has not been widely recognized in practice. Also, how the skid resistance for sidewalk should be measured to represent the irregular surface condition of sidewalks compared that of roadways will be important question.

Though the measurement method about British Pendulum Tester is defined well, the irregular surface condition of sidewalk prevents BPNs randomly measured within sidewalk from representing the whole performance of slip resistance. With this, the study tried to find out the skid resistance of various surface types including not only concrete interlocking block, colour asphalt pavement, but also the manhole, textile paving. From this, we hoped that more representative BPN can be acquired to explain the slip resistance of sidewalks. This study was mainly focused on the measurement of skid resistance in residence areas where various surface types are more frequently expected than other places. The study has placed much weight on the variance of skid resistance by surface types rather than the skid resistance measurement method itself. Also, the consistency of skid resistance along the pedestrian route is being importantly concerned at the study. Below contents are composing of British Pendulum Tester as an equipment, site description where the unique characteristics of this study are well illuminated, and measurement details in which the skid resistance results measured in snow-melting, sludgy, and snowy conditions of various surface types are summarized corresponding to the surface types. After these, comparison between road surface types, reduction rates of skid resistance in sludgy and snowy condition compared to skid resistance in snow-melting are analysed. The skid resistance variation along measurement points is analysed to find out the variation of skid resistance along the pedestrian route.

2. METHOD

2.1. British Pendulum Tester

This study used British Pendulum Tester (BPT) to measure the skid resistance of the sidewalk. The working mechanism of the Tester is defined ASTM E 303 (Standard Test Method for Measuring Surface Frictional Properties Using the BPT). The skid resistance is termed as British Pendulum Number (BPN) in case of using British Pendulum Tester. The increase of BPN means the increase of skid resistance and vice versa. Figure 1 shows the BPT which was used in our study. At every measurement, the levelling and equipment calibration were made to derive the value in an accurate manner. The surface temperature was also measured for the data adjustment with related to the temperature. The adjustment follows the method suggested in Installation and Management Guideline of Sidewalk in South Korea.

FIGURE 1. British Pendulum Tester

2.2. Site Description

This study measured the skid resistance using British Pendulum Tester while moving along the sidewalk in residence area under snow-melting, sludgy, and snowy conditions. At the every points of measurement, five trials were made to acquire the average and standard deviation skid resistance. Measurements were made on December 14, 2012 for snow-melting and sludgy, and on December 21, 2012 for snowy condition. Figure 2 shows the site condition and measurement points from P1 to P7 with pictures corresponding to the surface type listed like below.

- P1: Concrete Interlocking Block
- P2: Colour Asphalt Pavement
- P3: Concrete Manhole
- P4: Steel Manhole
- P5: Granite Block Paving
- P6: Concrete Textile Paving
- P7: Plastic Textile Paving

Measurements were made along the route mimic the walking trajectory of pedestrians at sidewalk, so skid resistance value itself and variation along the route can be analysed. The measurement site is located at Il-san District in Go-Yang City of South Korea. The measurement site is surrounded by residence featured by the apartment blocks and retail shops and buildings with five to ten stories. Although the whole distance along the study site is about 300 meters, the surface types are divided into seven points shown in Figure 2.

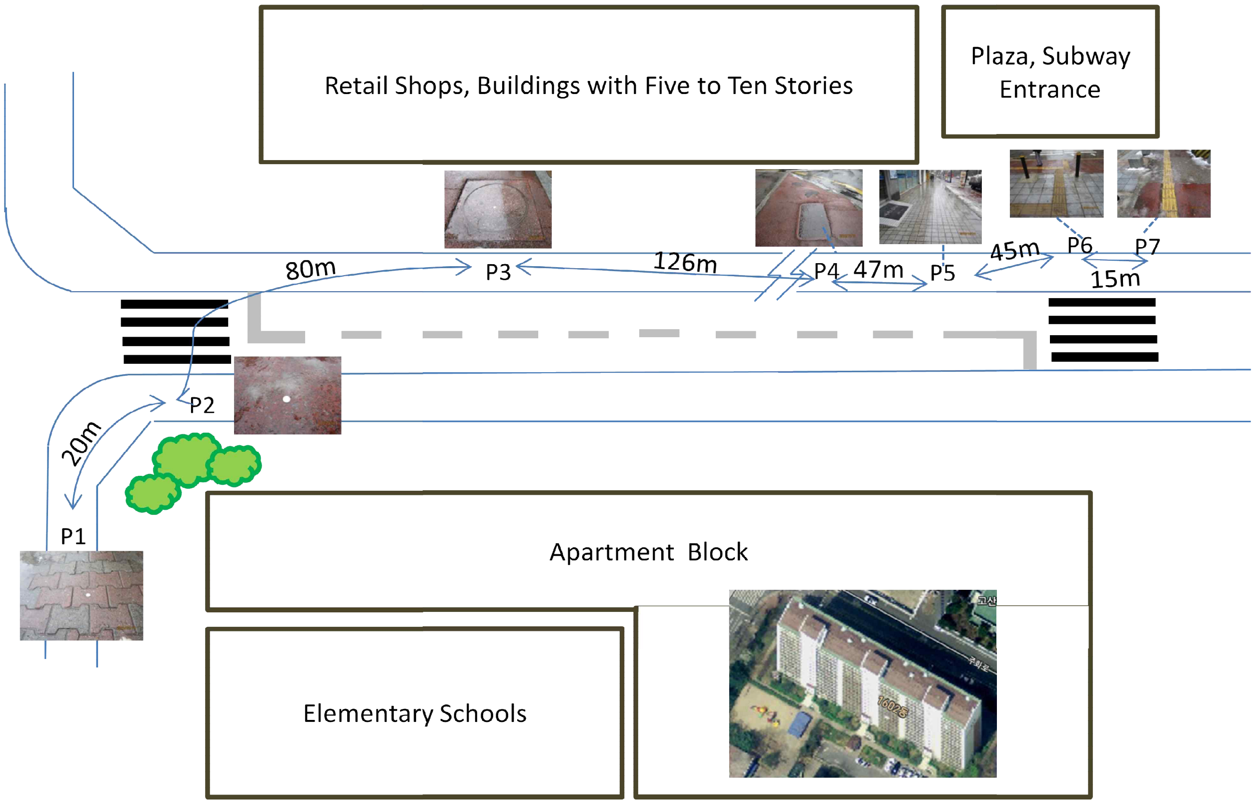


FIGURE 2. Measurement Points of Study Site

Concrete interlocking block is most popular type of pavement for Sidewalk in South Korea. And, colour asphalt pavement is installed mostly on the area for pedestrian waiting for crossing where the curb cut is needed to make wheel chaired users moving easier. Asphalt pavement is more workable for this curb cut rather than the interlocking block paving. Though manhole is not paving but the location of manhole is usually allocated not far from the centre line of the sidewalk, so the skid resistance of manhole should not be overlooked as far as this study concerned. Granite block paving is usually installed in front of the commercial buildings. The frontage area of building which is supposed to be used by public is decorated for the colour balance of buildings. Granite blocking paving is mostly used in these areas, and the size of block is quite variable at place by place. Textile paving for vision impaired is widely used in South Korea. However the criteria on the skid resistance of textile paving has not been made in South Korea yet, the skid resistance performance of textile paving is so varied depending the material such as concrete and plastic.

2.3. Measurement

Table 1 shows the measurement of skid resistance on concrete interlocking block in snow-melting, sludgy, and snowy conditions. In this study, the border between snow-melting, sludgy, and snowy condition are made by the judgement of observer. Relatively higher BPN were derived in snow-melting condition by the average of 88.0 in concrete interlocking block. However, the resistance was decreased to 52.8 and 55.8 in sludgy and snowy conditions.

TABLE 1 Skid Resistance of Concrete Interlocking Block (P1 in Figure 2)

Surface Type	Measurement Conditions		BPN	
			Avg.	S.D.
Concrete Interlocking Block Paving	Snow-Melting		88.0	1.41
	Sludgy		52.8	2.59
	Snowy		55.8	1.10

Table 2 shows the measurement of skid resistance on colour asphalt pavement in a wet after snow-melting, sludgy, and snowy conditions. Relatively higher BPN were derived in a wet after snow-melting on average of 87.4. However, the resistance was decreased to 50.8 and 58.4 in sludgy and snowy conditions.

TABLE 2 Skid Resistance of Colour Asphalt Pavement (P2 in Figure 2)

Surface Type	Measurement Conditions		BPN	
			Avg.	S.D.
Colour Asphalt Pavement	Snow-Melting		87.4	1.34
	Sludgy		50.8	0.84
	Snowy		58.4	2.07

Table 3 shows the measurement of skid resistance on manhole in snow-melting and snowy conditions. Average of 81.0 was acquired for manhole made of concrete and 50.6 in case of steel under wet condition. Skid resistance of manhole of steel in snowy was almost the same to the value acquired under snow-melting with the average value of 50.2. However, the measurement of manhole of concrete in snowy was not made due to the site condition, and the measurement of skid resistance in sludgy condition was not made.

TABLE 3 Skid Resistance of Manhole (Site P3 & P4 in Figure 2)

Surface Type	Measurement Conditions		BPN Avg.	BPN S.D.
Concrete Manhole	Snow-Melting		81.0	1.22
Steel Manhole	Snow-Melting		50.6	0.89
	Snowy		50.2	0.45

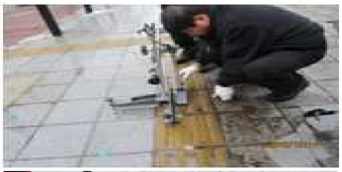
Table 4 shows the measurement of skid resistance on granite block paving in snow-melting and snowy conditions. In case of granite block paving, 53.2 on average in snow-melting, and 39.8 in snowy was acquired. The measurement of Sludgy condition was not made due to the site condition. In overall, the values acquired in granite block paving were lower than the values of interlocking block paving or asphalt pavement. Especially the value of 39.8 in snowy condition is slightly below the value recommended in South Korea Guideline for Curbs Skid Resistance.

TABLE 4 Skid Resistance of Granite Block Paving (Site P5 in Figure 2)

Surface Type	Measurement Conditions		BPN Avg.	BPN S.D.
Granite Block Paving	Snow-Melting		53.2	1.30
	Snowy		39.8	0.45

Table 5 shows the measurement of skid resistance on tactile paving for vision impaired in snow-melting and snowy conditions. Average of 89.4 and 24.8 was acquired for tactile paving made of concrete and plastic respectively. Skid resistance of tactile paving made of concrete is reduced to 62.6 on average in snowy, but the resistance of plastic tactile paving is almost the same to the value measured in snowy with the value of 24.4. The skid resistance between concrete tactile paving and plastic showed a big difference as shown in Table 5.

TABLE 5 Skid Resistance of Tactile Paving (Site P6 & P7 in Figure 2)

Surface Type	Measurement Conditions		BPN Avg.	BPN S.D.
Concrete Tactile Paving	Snow-Melting		89.4	0.89
	Snowy		62.6	0.54
Plastic Tactile Paving	Snow-Melting		24.8	0.45
	Snowy		24.4	0.55

2.4. Comparison between Surface Types

Figure 3 shows the skid resistance corresponding to surface types in snow-melting condition. In general, surface of concrete and asphalt material represented the higher values compared to the surface made of steel or plastic materials. However, the skid resistance of plastic tactile paving is lower than the skid resistance criteria (40BPN) for curbs of sidewalk recommend by Guideline of South Korea.

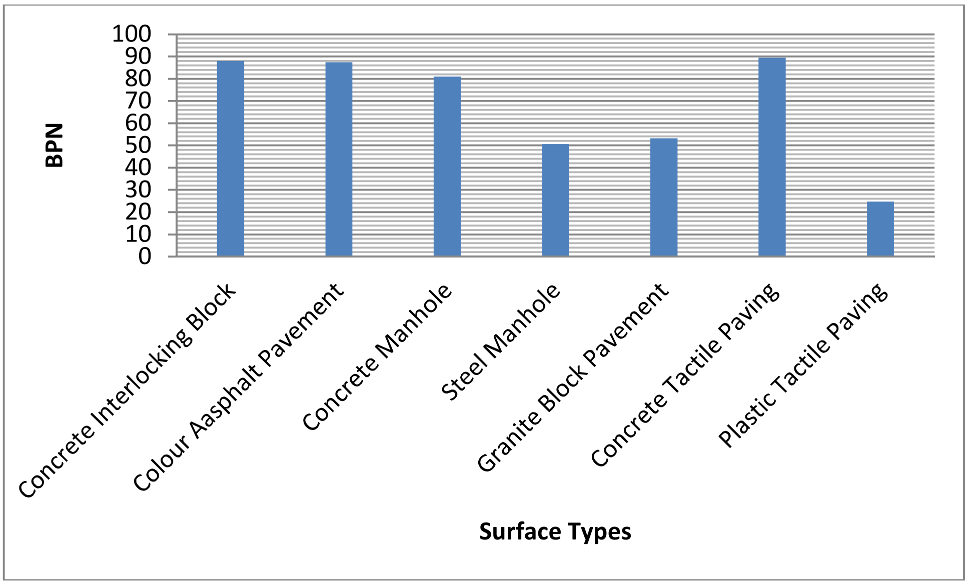


FIGURE 3. Skid Resistance Corresponding to Surface Types in Snow-Melting

Figure 4 shows the skid resistance corresponding to surface types in sludgy. Only two cases were measured, and the values were about 50 of BPN. Though this value is higher by 10 compared the value recommended by Guideline, the margin is not quite high.

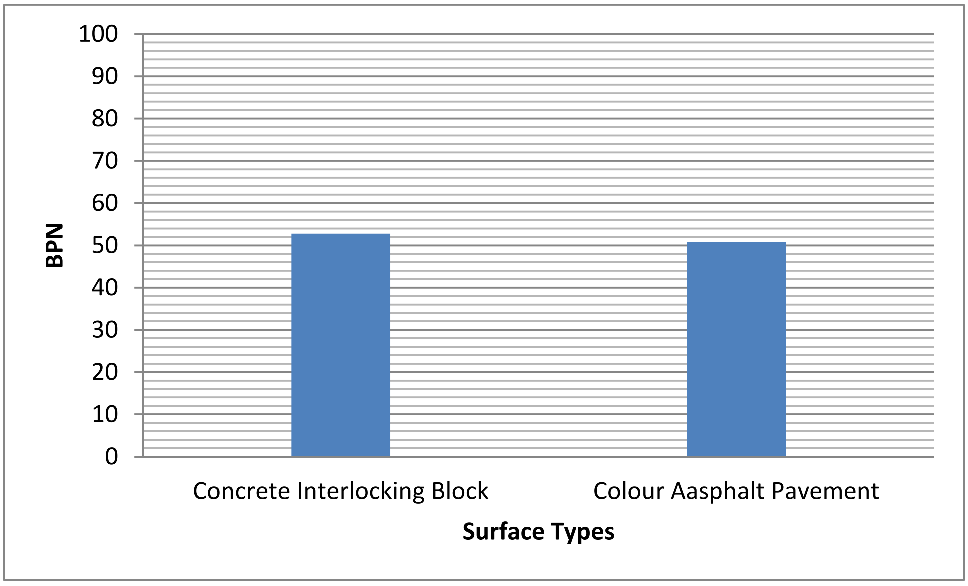


FIGURE 4. Skid Resistance Corresponding to Surface Types in Sludgy

Figure 5 shows the skid resistance corresponding to surface types in snowy condition. In case of snowy, the skid resistance across the surface types are not varied quite much except the plastic tactile paving. The skid resistance of steel manhole in snowy is not lowered compared to the snow-melting. Authors expected that the rough pattern of surface of steel manhole can be partly contributed the results. So, further research on the relationship between the macro pattern of surface and the skid resistance need to be studied.

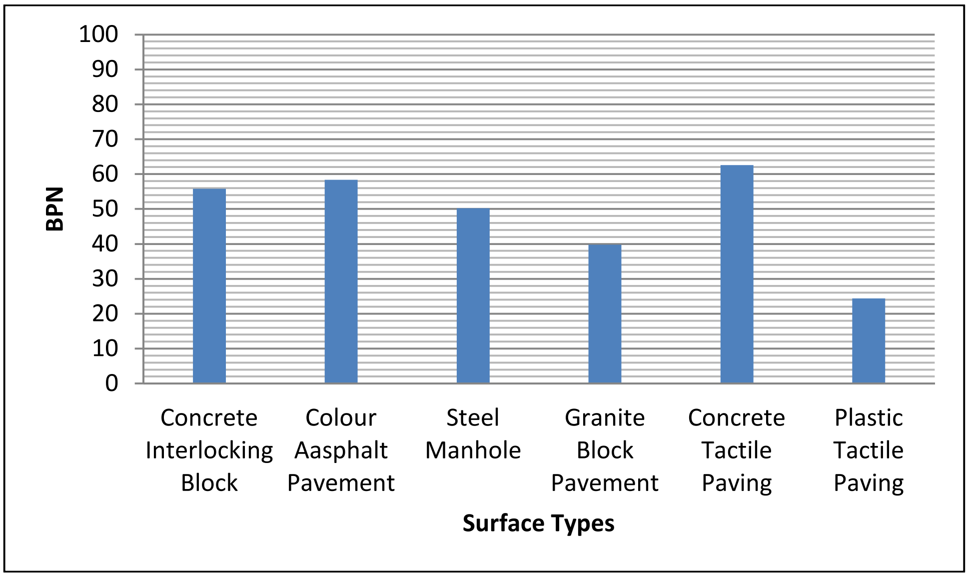


FIGURE 5. Skid Resistance Corresponding to Surface Types in Snowy

2.5. Reduction Rate

Table 6 shows the reduction rate compared to snow-melting condition. In typical paving such as interlocking block and asphalt pavement, reduction rate is around 40% in sludgy, 35% in snowy respectively. The reduction rate of granite block pavement and concrete textile paving is about 25 to 30% in each. However, the reduction rate of steel manhole and plastic textile paving is closed to 1%. It means that reduction of skid resistance both these surface types are not made.

TABLE 6 Reduction Rate Compared to Snow-melting Condition

Surface Type	Reduction Rate (%)	
	Sludgy	Snowy
Concrete Interlocking Block	40.0	36.6
Asphalt Pavement	41.9	33.2
Granite Block Pavement	N/A	25.2
Steel Manhole	N/A	0.8
Concrete Textile Paving	N/A	30.0
Plastic Textile Paving	N/A	1.6

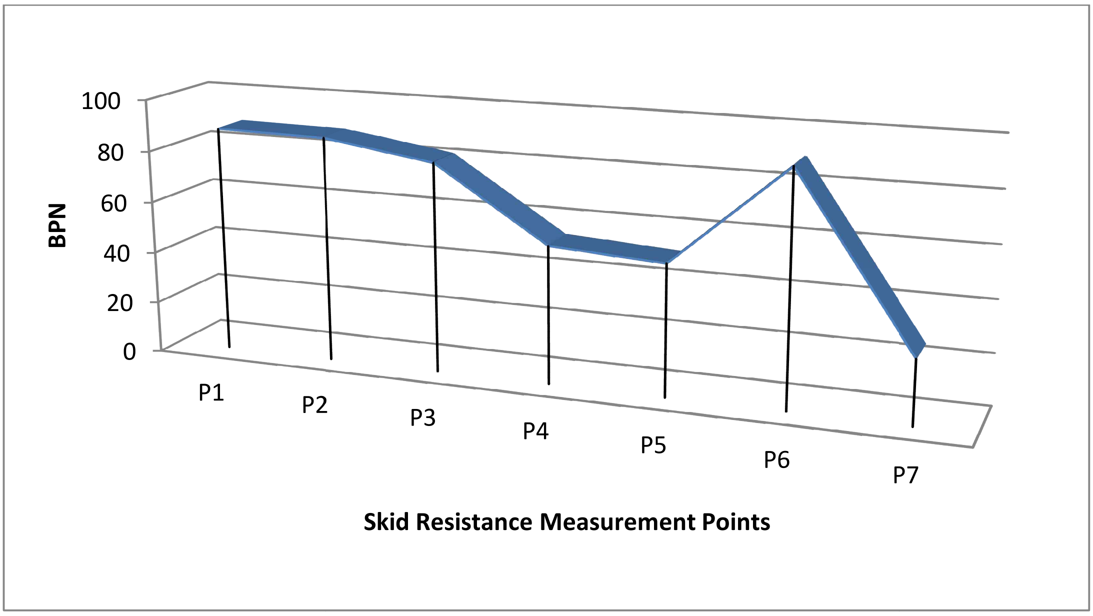
Note: Reduction Rate= (BPN1-BPN2)/BPN1*100
BPN1=BPN in Snow-Melting
BPN2=BPN in Sludgy or Snowy

2.6. Consistency of Skid Resistance along Route

As mentioned in the earlier part of this thesis, the weight on this study is placed on the consistency of skid resistance along the pedestrian route. Because pedestrians are not aware about the exact skid resistance of the surface they are walking on, the abrupt change of skid resistance is more likely to make pedestrians falling. Specially, pedestrians who are walking while texting or watching cellular phone are more likely vulnerable to the abrupt change of skid resistance. As far as this study concerned, there is no internationally accepted criterion or index of consistency of skid resistance along pedestrian route, it is difficult to judge whether some of the area within study site is violating the consistency or not. However, this study assumed that sharp drop or jump of skid resistance between sections or points can be regarded as violating the consistency.

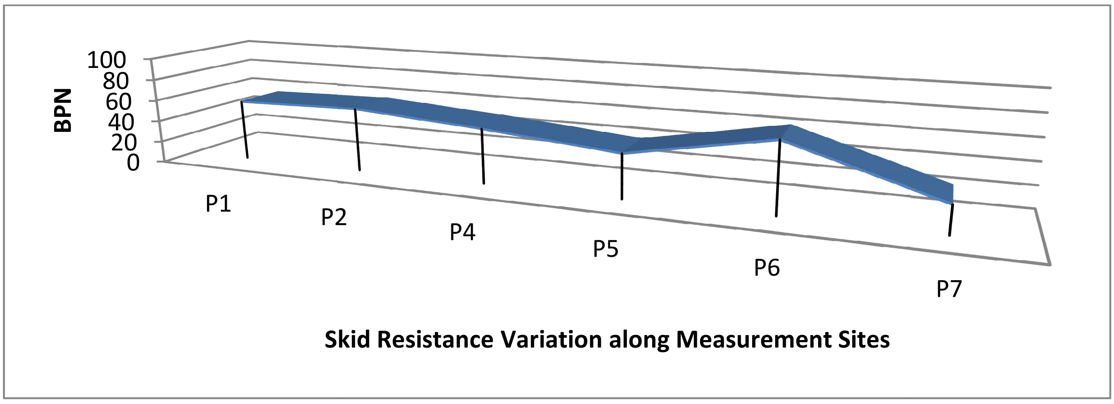
Figure 6 shows the variation of skid resistance along the pedestrian routes under snow-melting condition. The deep down is made at P4 (steel manhole) and P5 (granite block paving), and the most difference of skid resistance is found between P6 to P7 as like 64.6. Pedestrians have a skid resistance about 80 in BPN when they are starting to walk at P1 (Refer Figure 2 for the location of P1) where they are on the concrete interlocking block, and after 20 meters walking, they still have the similar level of skid resistance on colour asphalt pavement at P2 while they are waiting to cross the intersection. After crossing, pedestrians have met concrete manhole at P3, anyway, it is again the similar skid resistance as like 81.0, so consistency of skid resistance is still maintained. At point 4 with steel manhole, skid resistance is rapidly decreased to 50.6 and the consistency is violated at transition from P3 to P4 and P5 where granite block paving is existed. After this, pedestrians have a concrete tactile paving where skid resistance is relatively high as much as 89.4, so consistency is again violated from P5 to P6. Skid resistance is decreased to 24.8 at P7 which is few meters distanced from P6, so consistency is also violated from P6 to P7. Therefore, within study site, total three times of violation of consistency were occurred.

Figure 7 shows the variation of skid resistance under snowy condition along the pedestrian routes. The skid resistance at P3 (steel manhole) was not acquired due to site condition. As shown in Figure 7, the deep down is made at P5, and the most difference of skid resistance between P6 to P7 is 38.2 in BPN. Pedestrians have a skid resistance about 55 when they are starting to walk at P1 under snowy where they are on the concrete interlocking block, and after 20 meters walking, they still have the similar level of skid resistance on colour asphalt pavement at P2. After crossing, pedestrians have met steel manhole at P4, anyway, it is again the similar skid resistance as like 50.2, so consistency of skid resistance is said to be maintained. At P5 with granite block paving, skid resistance is dropped to 39.8, and the consistency is said to be violated at transition from P4 to P5. After this, pedestrians have a concrete tactile paving at P6 where skid resistance is relatively high as much as 62.6, so consistency is again violated from P5 to P6. Skid resistance is decreased to 24.4 at P7, so consistency is also violated from P6 to P7. Therefore, within study site, total three times of violation of consistency were occurred. However, only consistency points of view, the variation of skid resistance between points is lower than that of snow-melting condition. Also, the overall size of violation is lowered.



Note) P1: Concrete Interlocking Block, P2: Colour Asphalt Pavement, P3: Concrete Manhole, P4: Steel Manhole, P5: Granite Block Paving, P6: Concrete Textile Paving, P7: Plastic Textile Paving, See Figure 2 for location of P1 to P7)

FIGURE 6. Skid Resistance Corresponding to Surface Types in Snow-melting



Note) P1: Concrete Interlocking Block, P2: Colour Asphalt Pavement, P4: Steel Manhole, P5: Granite Block Paving, P6: Concrete Textile Paving, P7: Plastic Textile Paving, See Figure 2 for location of P1 to P7)

FIGURE 7. Skid Resistance Corresponding to Surface Types in Snowy

3. CONCLUSIONS AND FURTHER STUDY

As mentioned in abstract, few studies have addressed on the skid resistance of sidewalk in spite of the sharp growing rate of elderly people especially in South Korea. This study aimed to response two question such as how much the skid resistance is decreased with whether change such as wet after snow-melting, sludgy, and snowy conditions and how much the variation of skid resistance along the pedestrian route. The irregular surface of sidewalk relative to the surface of roadway leads the study including manhole and textile paving for vision. Within the scope of this study, we concluded that the skid resistance is varied depending on the paving materials and weather conditions. Secondly, the appropriate level of consistency of skid resistance should be controlled along the pedestrian route. Thirdly, a careful consideration should be made in placing manhole and paving for vision impaired not to lose the consistency along the pedestrian route. Future studies we recommended are the more detail study on the skid resistance of the manhole and textile paving which have a rough pattern on surface, and the study about the area-based evaluation of skid resistance of sidewalk as partially attempted in this study.

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