COST PERFORMANCE OF INTERLOCKING BLOCK PAVEMENT

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ABSTRACT

More than 20 years have passed since Inter-Locking Block Pavement (ILBP) was introduced in Japan. However, ILBP has found its applications mostly in sidewalks, squares, etc., and scarcely in streets. This limited dissemination of ILBP to streets is due to that fact that the main stream in street paving in the country is still low-cost Asphalt Pavement (ASP) . Taking as a subject of case study part of Koga City, Ibaraki Prefecture, where ILBP was introduced in streets in 1987, we made a survey to grasp how the roadside dwellers are conscious of pavement. This paper clarifies the valuations of ILBP and ASP by psychometric analysis (semantic differential method) and Contingent Valuation Method (CVM), based on the obtained results, and makes a cost analysis of both pavements with reference to the past results.

1. SITE OF SURVEY AND INVESTIGATION ITEMS

The site of this survey was an area of about 250,000 m^2 in and around Ohtemachi, the center of Koga City, Ibaraki Prefecture, shown in Figure 1. The streets in this area are of the type for common use of pedestrians and motor vehicles, called "Woonerf", and the streets as a whole are composed of a mixture of 10,600 m^2 of ILBP and 7,200 m^2 of ASP. Thus, about 60% of the streets are of the ILBP type. But the ratio of paved streets in the whole district of the city is 84%, of which only 2.3% is of the ILBP type.

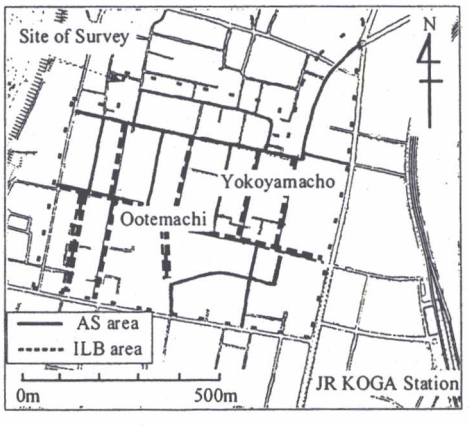

Figure 1 Map of the Site of Survey

The investigation items were as shown below. All of them were evaluated in five grades except the investigation of color preference and investigation of cost sharing.

(1) Valuation of impression by type of pavement by pair of adjectives.
(2) Valuation by walking comfort.
(3) Valuation by riding quality for motor vehicles.
(4) Valuation by riding quality for bicycles.
(5) Valuation by vehicle noise by dwellers.
(6) Valuation by water splashing by motor vehicles.
(7) Investigation of pavement color preference.
(8) Selection of pavement type by dwellers.

2. SURVEY OF ROADSIDE DWELLERS' CONSCIOUSNESS OF PAVEMENT

This survey was carried out by interviewing 650 persons living in the areas of both pavements (330 in the ILBP area and 320 in the ASP area), of which 246 persons gave

valid responses. The response rate was about 38%. A summary of the attributes of the samples is given in Table 1.

Table 1 Outline of Survey

No.of Sample	No.	246			
	%	100.0			
Sex		Male	Female	No Response	
	No.	117	128	1	
	%	47.6	52.0	0.4	
Dwelling Place		ILB area	AS area	No Response	
	No.	126	120	0	
	%	51.2	48.8	0.0	
Age		Teens	Twenties	Thirties	Forties
	No.	12	20	20	53
	%	4.9	8.1	8.1	21.5
		Fifties	Sixties	Seventies & Over	No Response
	No.	66	51	12	12
	%	26.8	20.7	4.9	4.9

2. 1 Valuation of Impression by Type of Pavement by Pair of Adjectives

We asked the roadside dwellers in the areas of both pavements to evaluate their everyday impressions of ILBP and ASP in five grades (-2 to +2 points) by the pairs of adjectives shown in Table 2.

Table 2 Pairs of Adjectives

+2	+1	0	-1	-2
Fresh				Heavy
Comfortable				Uncomfortable
Pleasant				Unpreasant
Refind				Unrefind
Open				Closed
Beautiful				Ugly
Safe				Dangerous
Quiet				Noisy
Natural				Artificial
Clean				Dirty

Average of the scores of both pavements, given by the samples for each valuation item, were calculated, and a principal component analysis was made based on the obtained values. The results are given in Table 3. The cumulative contribution rate of the 1st order and 2nd order principal components is 97.4%, so the dwellers_ pavement valuation structure can be explained by these two components. As a result of the investigation made into the factor loading of each valuation item, the 1st order principal component can be interpreted as a valuation axis pertaining to "refinement" and the 2nd order principal component as a valuation axis pertaining to "emotionality". Next, by showing the score on the 1st order principal component of each item on the valuation axes composed of the 1st order and 2nd order principal components, the respondents are divided into the following three groups as shown in Figure 2.

(1) Group high in both refinement and emotionality.
(2) Group rather high in refinement but low in emotionality.
(3) Group low in refinement but high in emotionality.

Table 3 Result of Principal Component Analysis

	Component1	Component 2	Component 3	Conponent4
Fresh	0.235	0.108	-0.031	0.044
Comfortable	0.335	0.371	0.403	0.110
Preasant	0.731	-0.955	0.109	-0.240
Refind	1.984	0.317	-0.214	-0.107
Open	0.172	-0.999	-0.268	0.040
Beautiful	2.058	0.663	0.323	-0.129
Safe	-2.842	0.654	-0.331	-0.206
Quiet	-3.254	0.339	0.216	0.079
Natural	-0.917	-1.008	0.137	0.142
Clean	1.498	0.510	-0.343	0.268
Characteristic Value	3.406	0.491	0.077	0.027
Contribution Rate	85.1	12.3	1.9	0.7

Figure 3 shows the relation between the score on the 1st order principal component of each item and the total score on the valuation item, by area and by type of pavement. As seen from the Figure, a positive correlation (correlation coefficient over 0.9) exists for ILBP, which means that the respondents' impressions are favorable, and a negative correlation (correlation coefficient over 0.7) exists for ASP, which means that the respondents' impressions are not so favorable.

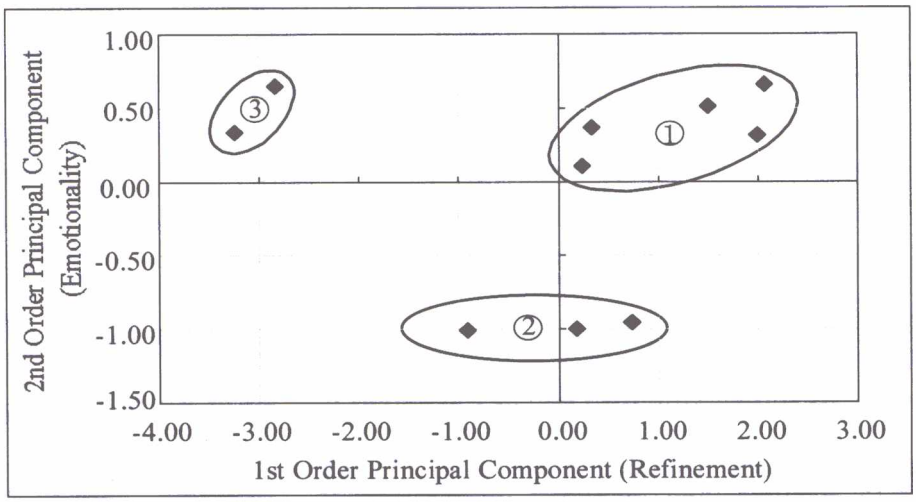

Figure 2 Principal Component Score

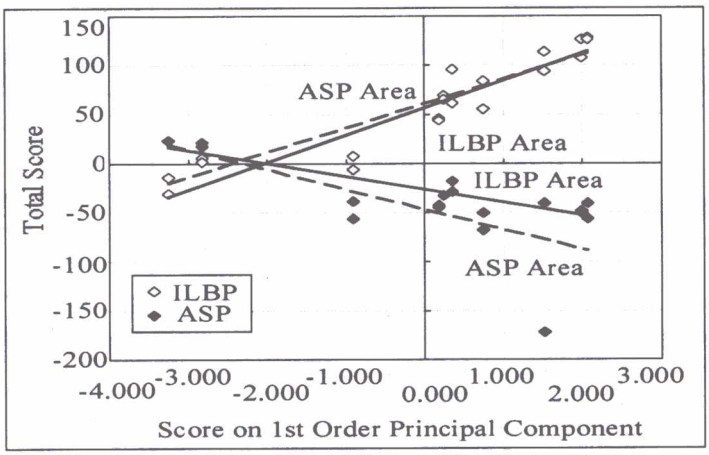

Figure 3 Total Score Vs. Principal

2.2 Valuation by Walking Comfort

Concerning the walking comfort in both fine weather and rainy weather, we evaluated ILBP and ASP in five grades. The results are given in Figure 4.ILBP is inferior to ASP in the score in fine weather. On the contrary, in rainy weather, the score of ILBP is positive, while that of ASP is negative. It is characteristic that the score of ILBP in rainy weather is high particularly in the ASP area. This means that the draining function of ILBP having joints contributes to better walking comfort.

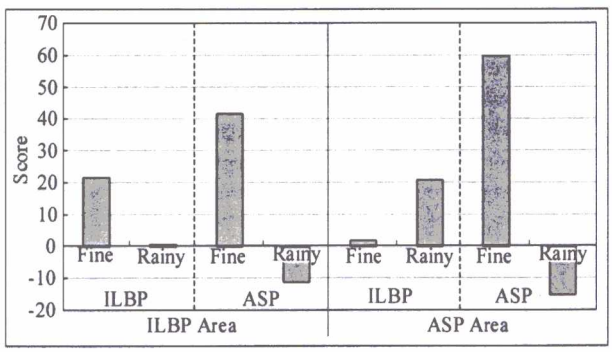

Figure 4 Walking Comfort

2.3 Valuation by Riding Quality for Motor Vehicles

Concerning the riding quality for motor vehicles in both fine weather and rainy weather, we asked those who usually drive motor vehicles (86 persons) to evaluate ILBP and ASP in five grades. In this connection, it should be noted that the running speed specified for the roads surveyed is 30 km/h or less because they are for common use of pedestrians and motor vehicles. As a result, it was found that ASP is superior, irrespective of the weather, as shown in Figure 5. ILBP in rainy weather is given a high score only by the subjects in the ILBP area.

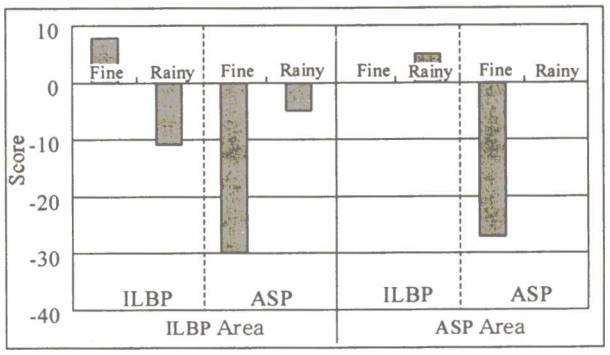

Figure 5 Riding Comfort for Motor Vehicles

2.4 Valuation by Riding Quality for Bicycles

Concerning the riding quality for bicycles in both fine weather and rainy weather, we asked those who usually drive bicycles (230 persons) to evaluate ILBP and ASP in five grades. As shown in Figure 6, it became clear that ASP is superior in both areas, and that ILBP is not in favor with cyclists. The reason for this seems to be attributable to the fact that the blocks in the areas surveyed are 10-odd years old and have a large chamfer and a wide joint spacing although they still maintain a relatively good flatness. Consideration for joint spacing is linked, of course, to consideration for wheelchair users.

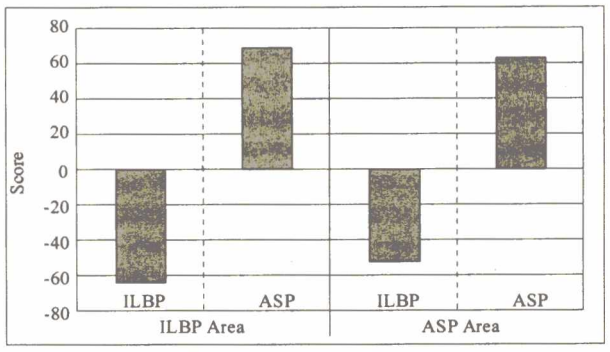

Figure 6 Riding Comfort for Bicycles

2.5 Valuation by Vehicle Noise by Dwellers

Concerning the vehicle noise during walking in both fine weather and rainy weather, we asked the roadside dwellers to evaluate ILBP and ASP in five grades according to their personal feeling. The results are given in Figure 7. In fine weather, ASP is apparently given a high score. On the contrary, ILBP is given a negative score. In rainy weather, however, the scores of both pavements are negative, but there is no difference in valuation between them. According to another study on noise [1], the noise level on ILBP is 3-4 dB(A) lower than ASP at running speeds over 30 km/h, but the subjects seem to be sensitive to shock sounds at low frequencies generated from the joints by motor vehicles running at low speeds.

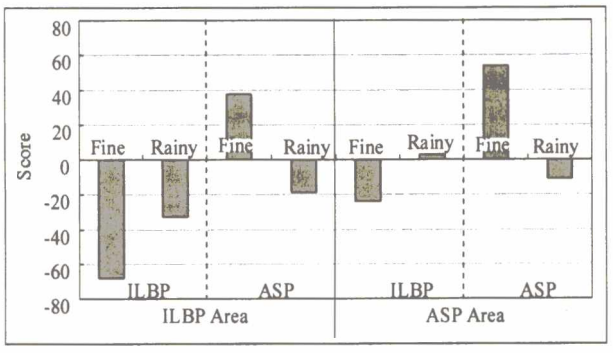

Figure 7 Vehicle Noise

2.6 Valuation by Water Splashing by Motor Vehicles

In the case of streets of small width (4-7 m) for common use of pedestrians and motor vehicles, water splashing by motor vehicles running in rainy weather poses a problem. This is a matter of great concern to pedestrians. Therefore, concerning the degree of discomfort caused by water splashing, we evaluated ILBP and ASP in five grades. The results are given in Figure 8. The score of ILBP is high. On the contrary, the score of ASP is very low. This substantiates that ILBP in rainy weather was rated high by the subjects in the ASP area in the above-mentioned investigation by walking comfort.

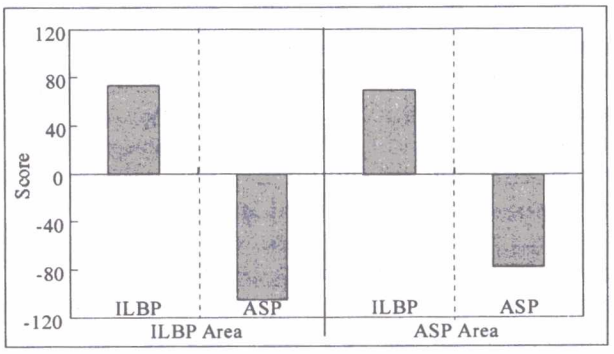

Figure 8 Water Splashing

2.7 Investigation of Pavement Color Preference

The great difference between ASP and ILBP is in the color of pavement. It is already pointed out that the rhythmical sense created by joints enriches the street environment [2]. To investigate the dwellers' color preference, we asked them to mention what color they think suitable for pavement, allowing them to make plural responses by selecting from 8 kinds of colors shown in Figure 9.

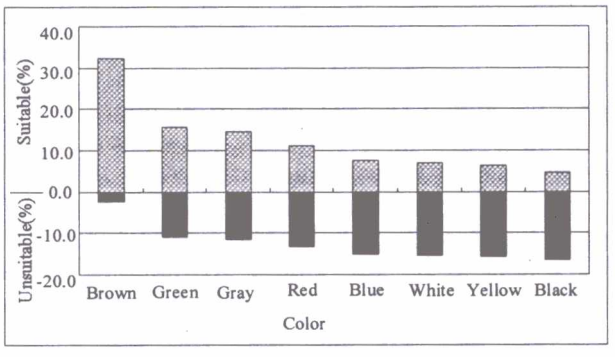

Figure 9 Pavement Color

In the areas surveyed, the ratio of the respondents who considered the brown color suitable was 33%. In contrast, the black and yellow colors were mentioned as unsuitable ones. The top three kinds of colors judged suitable in this survey agree with those obtained by Miura's survey [2] in Atami City in 1981 though some difference exists. In terms of the preference of pavement color, therefore, it seems that there is something common among the Japanese people.

2.8 Selection of Pavement Type by Dwellers

Taking into account the above results and indicating that ILBP would require a high construction cost of ¥3,000/m^2 or more and a long construction period, we asked the dwellers to mention which of the two types of pavement they would like to select for the future. The results are given by pavement area in Figure 10. ILBP was selected by about 62% of the dwellers in the ILBP area where it had already been disseminated with a fairly high density, and was wanted by 54% even in the ASP area. On the other hand, ASP was supported by one out of three. Therefore, it would be necessary to give due consideration to such consciousness of the roadside dwellers when pushing forward street reconstruction plans for the future.

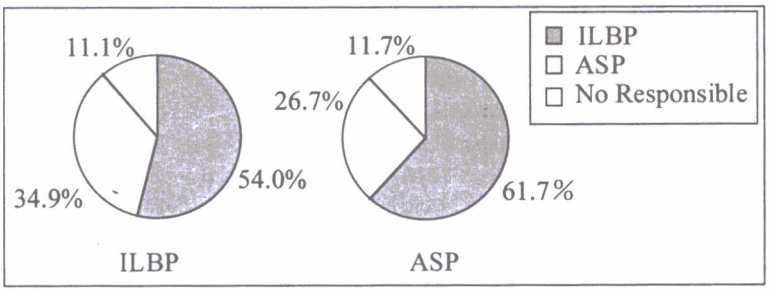

Figure 10 Pavement Selection

3. INVESTIGATIN OF COST SHARING FOR PAVEMENT (CVM)

We attempted to evaluate the dwellers' interest in both pavements and the potential value of ILBP by investigating the amounts of money the community would have a will to pay for street paving, along with the above-mentioned investigation items.

Telling that the administration would not request the citizens to share any extra costs for road paving in the future as before, we investigated possible amounts of money to be borne per household, assuming ILBP as a choice for road paving. For this investigation, the amounts of money were estimated and proposed in the range from "Do not bear" (¥0) up to ¥3,000 in increments of ¥500. The results are shown by pavement area in Figures 11 and 12 in the form of a distribution diagram of the acceptance rates of the proposed amounts. The subjects who refused to pay held a majority in both areas, but 38% of the dwellers in the ILBP area and about half (48%) in the ASP area accepted to bear an amount of ¥500 or more. Moreover, the ratio of those who accepted to bear ¥3,000 was only 3% in the ILBP area, while it increased to 11% in the ASP area. Thus, it is presumed that the dwellers in the ASP area though small in number take a positive attitude to the introduction of ILBP as is apparent from the results of the above-mentioned consciousness survey.

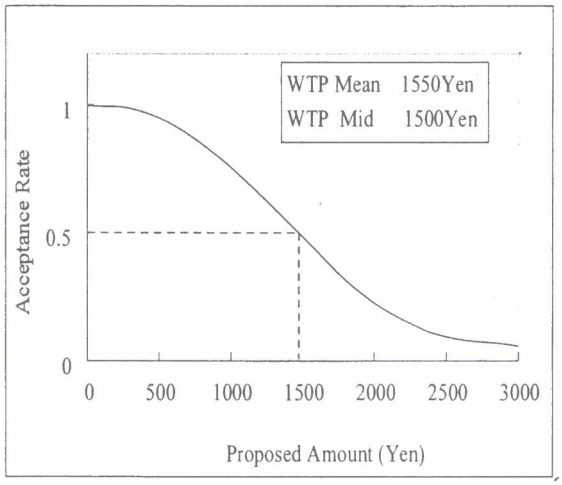

Figure 11 WTP Amount in ILBP Area

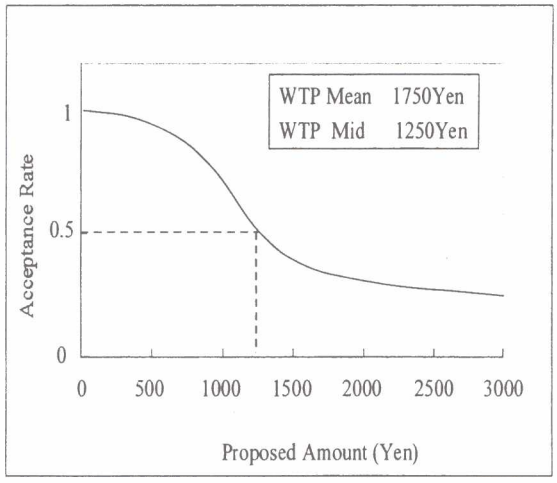

Figure 12 WTP Amount ASP Area

Concerning the Will To Pay (WTP), the mean value of WTP amount was ¥1,550 in the ILBP area, while it increased to ¥1,750 in the ASP area. The mid-value was ¥1,500 in the ILBP area, while it decreased to ¥1,250 in the ASP area. Therefore, it became clear that the dwellers in the ASP area take a positive attitude to the introduction of ILBP, but show a somewhat negative attitude to bearing an excessive burden. Assuming the WTP amount as ¥1,250, the total amount to be borne by all households in the areas surveyed is ¥812,500 (= ¥1,250 x 650 households). This amount corresponds to 34.5% of the cost of ¥2,353,000 spent for maintenance and repairs of 682 m^2 of ASP in the areas surveyed in the past 10 years, in other words, the maintenance and repair cost for four years.

4. COST ANALYSIS OF PAVEMENT (LIFE CYCLE COST)

The life cycle cost is a concept on the basis of which to investigate the long-term economics of pavement. It is the sum of the construction cost of a new pavement and the total cost required over a long period of time after opening to traffic and is evaluated by converting to the Present Worth Of Cost (PWOC) by the ordinary discount rate. In Japan, the ILBP construction cost is said to be 1.3-1.8 times the ASP construction cost. As compared with the assumed ASP life of 10 years, the ILBP life is so long as to withstand the service conditions without trouble even after 20 years' service [3], and is 30-40 years according to B. Shackle [4]. Even in repair works (including paving works incidental to

maintenance and repairs of buried materials) of the pavement being in service, the blocks are reusable, and their residual value is strikingly high compared with asphalt mixes. Therefore, we made a cost analysis for a period of 30 years, based on some assumptions established with reference to the areas surveyed.

4.1 Assumptions for Cost Analysis

The established assumptions are as follows:

(1) The paving area is 10,000 m^2 for each type of pavement.
(2) The initial construction cost is ¥11,000/m^2 for ILBP and ¥8,000/m^2 for ASP.
(3) The annual maintenance and repair cost was assumed from the results of Koga City in the past 10 years as follows.
(4) The maintenance and repair area of ILBP is 180 m^2 per 10 years, and its maintenance and repair cost is ¥5,500/m^2.
(5) The maintenance and repair area of ASP is 383 m^2 per 10 years, and its maintenance and repair cost is ¥3,450/m^2.
(6) The maintenance and repair area is increased by 10% of that in the preceding 10 years at 10-year intervals.
(7) The ILBP life is 30 years. ILBP's blocks worth ¥6,000/m^2 lose their value by 1/3 at 10-year intervals, and the residual value after 30 years is ¥0. The repair cost after 30 years is ¥7,600/m^2.
(8) The ASP life is 10 years. Each time, all surface is subjected to repair by overlay. The repair cost after 10 years is ¥3,800/m^2. The residual value of the surface course is ¥0.
(9) The bases of both pavements are sound and maintain a residual value of ¥5,000 throughout 30 years.
(10) The discount rate is 3%.

4.2 Calculation of Present Worth of Cost (PWOC)

Figure 13 shows the PWOC calculated by the following equation on the basis of the above assumptions:

$$PWOC = C + M\frac{(1+i)^n - 1}{i(1+i)^n} + \frac{R}{(1+i)^z} - \frac{S}{(1+i)^n} \quad (1)$$

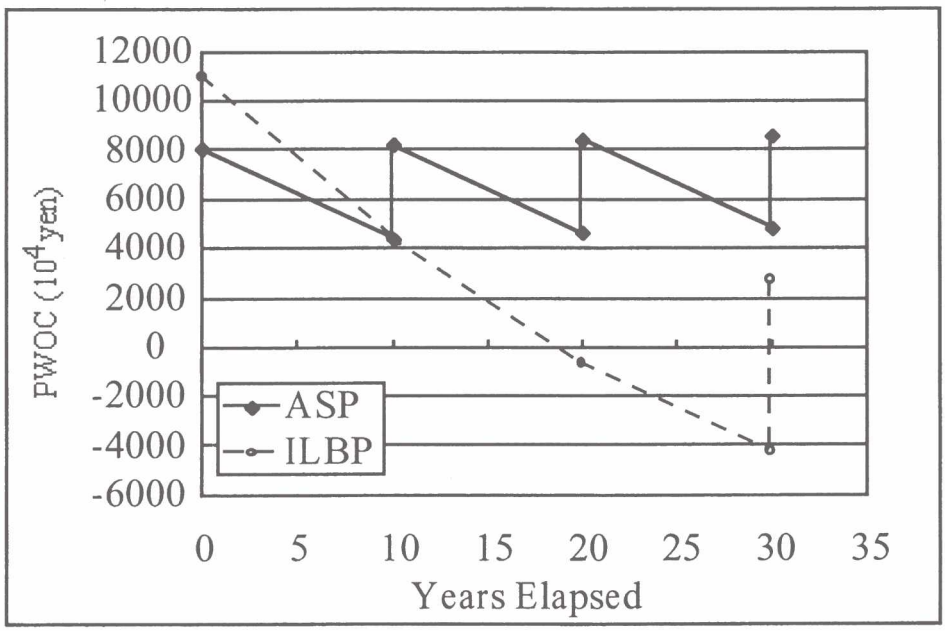

Figure 13 Present Worth of Cost (PWOC)

As apparent from the Figure, the PWOC of ILBP continues decreasing for 30 years and reaches a negative value after 20 years. This means that ILBP low in maintenance and repair cost and high in residual value recovers the investment cost and then serves as a stock. Assuming both pavements to be repaired after 30 years, ILBP having an initial value of ¥6,000/m^2 will be advantageous.

Though bold assumptions have been made for the cost analysis, ILBP which is about 40% higher in initial investment cost can be presumed to be advantageous over ASP because it is capable of being in service for a longer period of time. If we apply the assumptions to the areas surveyed, the maintenance and repair cost invested during 10 years will amount to ¥2,353,000 for 682 m^2 of ILBP and ¥1,762,000 for 320 m^2 of ASP. And the difference of ¥591,00 between the two amounts of money will correspond to 73% of the WTP amounts shown by the dwellers. Therefore, the selection of ILBP would obtain the dwellers' consent in terms of not only its contribution to improving the road environment such as landscape but its cost performance as well.

5. CONCLUSION AND POSTSCRIPT

We compared ILBP and ASP as to people's feeling and cost consciousness, referring to the consciousness of the roadside dwellers as street users. It became apparent from the factor analysis that the dwellers in the ILBP area have an attachment to ILBP, and that those in the ASP area also take a negative attitude to ASP as compared with ILBP.

For the selection of pavements, we could show to some degree the importance of not only the dwellers' consciousness but also of making cost analysis without adhering to the initial investment cost.

In the course of this survey, we could recognize it necessary for the dwellers to take part more actively in information disclosure and road administration in order to maintain the road environment in good condition as well as to enhance their awareness of streets belonging to them.

We would like to thank the dwellers concerned and the president of the self-government association for their cooperation in this very troublesome survey by interview. We are also grateful to the members of the Road Construction Section, Koga City Office, for their assistance in collecting data and for their kindness of introducing us to the site of the survey, and to Mr. N.Hagio and Mr. T.Aoki, Department of Transportation and Civil Engineering, College of Science and Technology, Nihon University, for their help in conducting the survey and analysis. The subsidy granted for this survey by the Japan Interlocking Block Pavement Engineering Association is gratefully acknowledged.

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