Development of color flexible pavement applicable to elementary school zone

S.-J. Lee[1], S. N. Amirkhanian[1] & K. W. Kim[2]
[1]*Department of Civil Engineering, Clemson University, USA*
[2]*Department of Infrastructures Engineering, Kangwon National University, South Korea*

Abstract

There have been increasing demands to use bright color pavements for elementary school zones, giving a warning sign to drivers and protecting the children. This study was initiated to investigate the applicability of color flexible concrete pavement (CFCP) for elementary school zones in South Korea. Color flexible pavement has been applied to non-motorway pavements, such as pedestrian and bicycle roads. This paper presents the engineering properties of color flexible concrete pavement used for motorway pavement of elementary school zones. A commercial polymer of low-density polyethylene (LDPE) was used to modify the transparent binder and to increase the performance characteristics of color flexible concrete pavement. Waste paper was used to prevent the binder draindown of gap-graded mixture. Evaluation of the mixtures included the following testing procedures: Marshall stability, indirect tensile strength (ITS), and permanent deformation. The results from this study showed that 1) the color asphalt concrete mixtures used in this study had nearly the same quality in engineering properties when compared with conventional asphalt concrete mixtures, and 2) there have been no apparent problems in application of color flexible pavement in the field, especially in the elementary school zones.
Keywords: safety, elementary school zone, CFCP, flexible pavements.

1 Introduction

In general, there is heavy traffic in the vicinity of elementary schools during the start and end times of school sessions. As children are vulnerable road users with limited experience using the roads, it is a principal concern to keep elementary

WIT Transactions on The Built Environment, Vol 94, © 2007 WIT Press
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/SAFE070421

school zones safe. The safety of school zones requires the joint effort of authorities, schools, parents, motorists and the community [1]. A road of elementary school zone should perform its special function to protect the children. Therefore, there are increasing demands for using bright color pavements for elementary school zone, reminding motorists to drive more carefully.

Flexible pavement is the most widely used pavement for various roads in the world, because of convenience of construction and maintenance, and fast traffic opening after construction. The color of conventional flexible pavement for normal road is black. Occasionally, color flexible concrete pavements are used for non-motorway pavements, such as bicycle road and walking path. In general, color flexible concrete pavements have inferior quality to be used for normal road pavements, which should sustain with a high pressure under heavy vehicles.

This study deals with developing the color flexible concrete pavement for motorway pavement of elementary school zone using a transparent binder and evaluating its properties in comparison with conventional asphalt concrete. Based on the previous studies [2–5], the contents of pigment, LDPE, and waste paper were selected. Four asphalt mixtures were designed using Marshall mix design. Several properties of these mixtures, including Marshall stability, indirect tensile strength, and rutting resistance were evaluated. The developed color flexible concrete pavement was incorporated into a lot of elementary school zones in South Korea and the field investigation was carried out.

2 Experimental program

2.1 Material

A transparent binder (TB) and a conventional asphalt binder (AB) were used for the color flexible concrete pavement and normal asphalt concrete, respectively. Table 1 shows the physical properties of the two binders. A coarse aggregate with the maximum size of 19mm was used for preparation of a gap-graded mixture together with a screenings as fine aggregate and mineral filler. Table 2 shows the properties of the aggregates.

Various color powders were used to produce color pavement mixtures by dyeing binder and aggregates. The pigment is powder type material passing #200 sieve over 95% by weight. Figure 1 shows a picture of several pigments. However, mechanical properties reported in this paper indicate the results of yellowish pavement mixtures (1.5% by binder weight [2]). The two binders of TB and AB were modified using a commercial polymer, a low-density polyethylene (LDPE). LDPE is a powder type material passing #50 sieve over 95% by weight, as shown in Figure 2. The content of LDPE was selected as 5% (for TB) and 6% (for AB) by weight of binder from previous studies [3, 4].

When gap-graded aggregates are used, a fiber is usually used to prevent a binder draindown and stabilize a mixture. In this study, waste paper in small-size pieces (2mm × 2mm) was added in the mixture instead of a commercial fiber, as shown in Figure 3. The content of waste paper was determined as 2% by weight of binder from a previous study [5].

Table 1: Physical properties of two binders.

Test properties	AB	TB
Penetration (25°C, 0.1mm)	94	92
Absolute viscosity (60°C, poise)	1,111	1,062
Ductility (25°C, cm)	150	-
Flash point (°C)	317	-
Softening point (°C)	46	46
Specific gravity	1.03	-

Table 2: Physical properties of aggregates.

Test properties	Specification	Coarse aggregate	Fine aggregate	Mineral filler
Specific gravity	> 2.45	2.72	2.72	2.75
Absorption (%)	< 3.0%	0.70	0.26	-
Abrasion (%)	< 35%	18.10	-	-

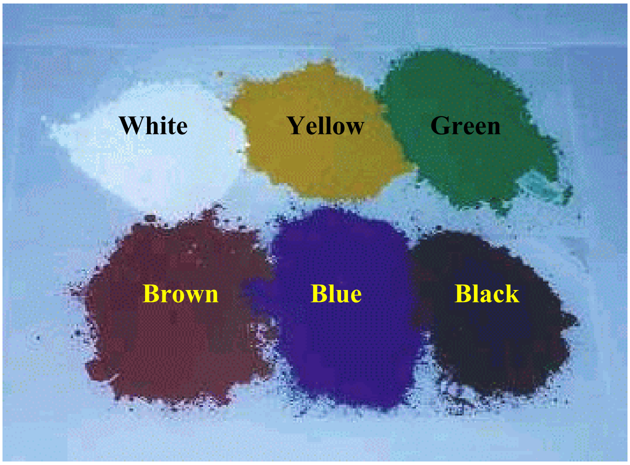
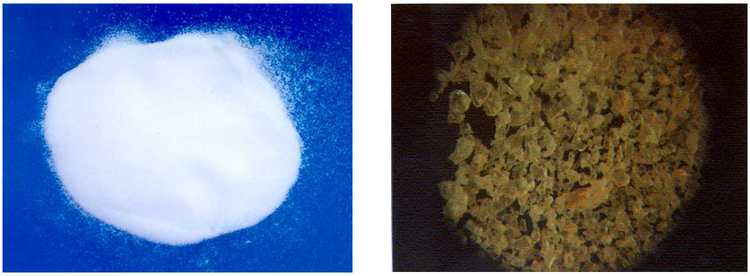


Figure 1: Pigment.



(a) (b)

Figure 2: LDPE (a) original, (b) magnification (×20).

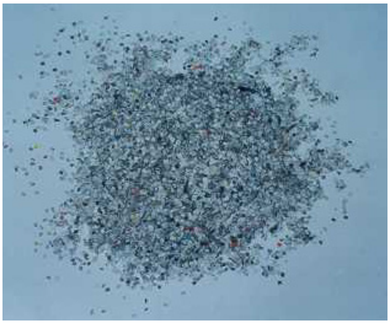


Figure 3: Waste paper.

2.2 Methods

Marshall mix design for each mixture was performed based on the following specification; 4% air void, 70-85% void filled with asphalt (VFA), minimum 500 kgf Marshall stability, and 20-40 flow values [6]. With regard to the mixtures modified with LDPE, approximately 15°C higher temperature than control mixture was used for heating and mixing materials to obtain a good workability. Optimum asphalt content (OAC) of each mixture was determined from the mix design. Table 3 shows the designation of mixtures used in this study.

Marshall stability and indirect tensile strength (ITS) were measured on Marshall specimens (100 mm diameter and 63 mm height). The static loading for Marshall stability and ITS test was 50 mm/min. The specimens were cured at 25°C for over 16 hours before testing. From ITS test, stiffness index (SI) was calculated using load-deformation curve (Figure 4).

The slab specimen (30cm × 30cm × 6.2cm) at OAC was made using a pneumatic-pressure controlled roller compactor with a target air void of 4 ± 0.5%. The specimen was kept in a room temperature for 48 hours before conditioning 6 hours at 60°C for wheel tracking test. In the wheel tracking system, moving wheel load was applied to the top of slab specimen through a steel wheel (200mm diameter) which is rolling back and forth at a speed of 0.5 Hz. The applied vertical load through the wheel was 70kgf and a total of 2,700 cycles were applied. Vertical deformation was measured using a LVDT and recorded through a computer. The dynamic stability (DS) which is the number of cycle required for the mixture to deform 1 mm vertically was measured between 500 and 2500 cycles (Figure 5) [4]. Figure 6 shows a flow chart of the experimental design procedure used in this study.

Table 3: Mixture designation.

Designation	Binder	Pigment (%) by wt. of binder	LDPE (%) by wt. of binder	Waste paper (%) by wt. of binder
G-AB	AB	0	0	2
G-TB	TB	1.5	0	2
G-ABL	AB	0	6	2
G-TBL	TB	1.5	5	2

Legend: G (Gap-graded aggregate), AB (Asphalt binder),
TB (Transparent binder), L (LDPE).

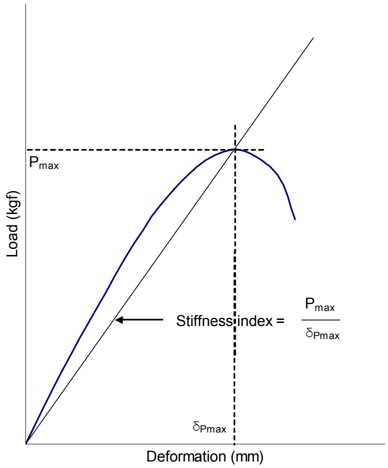


Figure 4: Stiffness index.

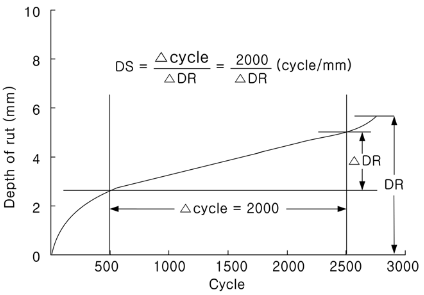
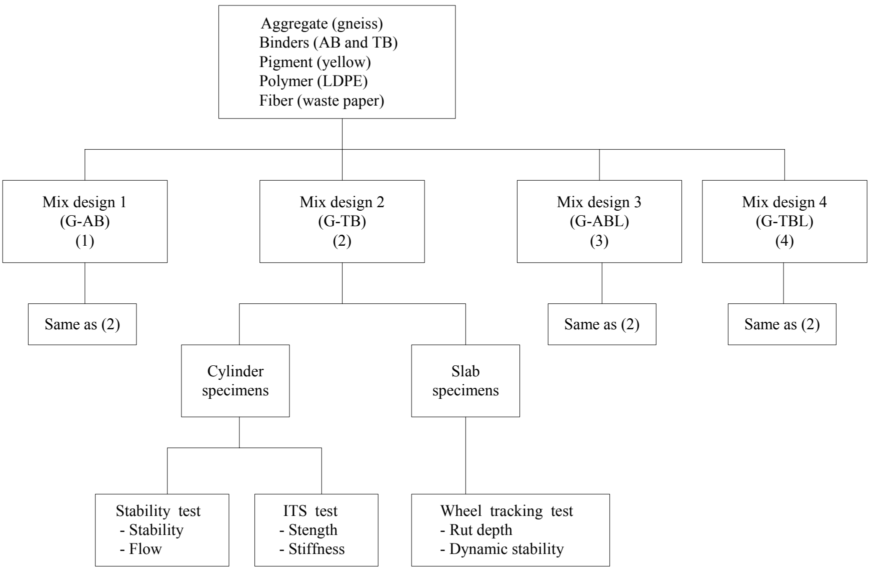


Figure 5: Dynamic stability.



Legend: G (Gap-graded aggregate), AB (Asphalt binder), TB (Transparent binder), L (LDPE).

Figure 6: Experimental design procedure.

Table 4: Marshall and ITS properties.

Mixtures	OAC (%)	Stability (kgf)	Flow (0.01cm)	ITS (kgf/cm^2)	SI (kgf/mm)
G-AB	4.8	909	35	9.3	445
G-TB	5.3	817	39	11.7	600
G-ABL	5.1	989	34	10.1	531
G-TBL	5.2	963	37	12.7	690

3 Results and discussion

3.1 Marshall stability and indirect tensile strength (ITS)

Table 4 shows Marshall and ITS properties of four mixtures. From the mix design, the optimum asphalt contents (OAC) were found to be 4.8, 5.3, 5.1, and 5.2% for the mixtures of G-AB, G-TB, G-ABL, and G-TBL, respectively. All mixtures used in this study satisfied the requirements of Marshall properties set forth by Korea Ministry of Construction and Transportation (KMCT) (minimum

500kgf stability and 20-40 flow values). G-TBL mixture (the color asphalt mix modified with 5% LDPE) showed the highest tensile strength and stiffness values. In general, LDPE modification was effective in improving strength properties of the mixtures.

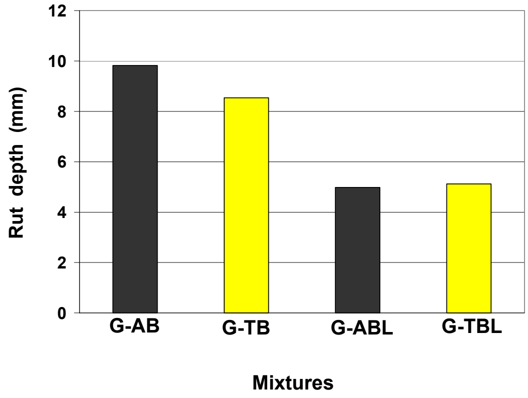


Figure 7: Final rut depth.

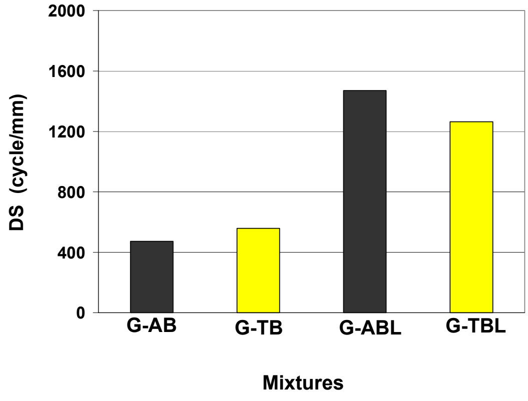


Figure 8: Dynamic stability.

3.2 Wheel tracking test

The final rut depth and the dynamic stability (DS) of each mixture were determined and the results are illustrated in Figures 7 and 8, respectively. Since the test simulates the pavement condition under a high pressure vehicle at 60°C, the lower rut depth and the higher DS represent greater resistance against permanent deformation. G-ABL mixture was found to be the best performing pavement (the lowest final rut depth and greatest DS) and G-TBL was the next. The DS of G-TBL mixture was 2.7 times greater than G-AB mixture, which is normally used in a conventional flexible pavement.

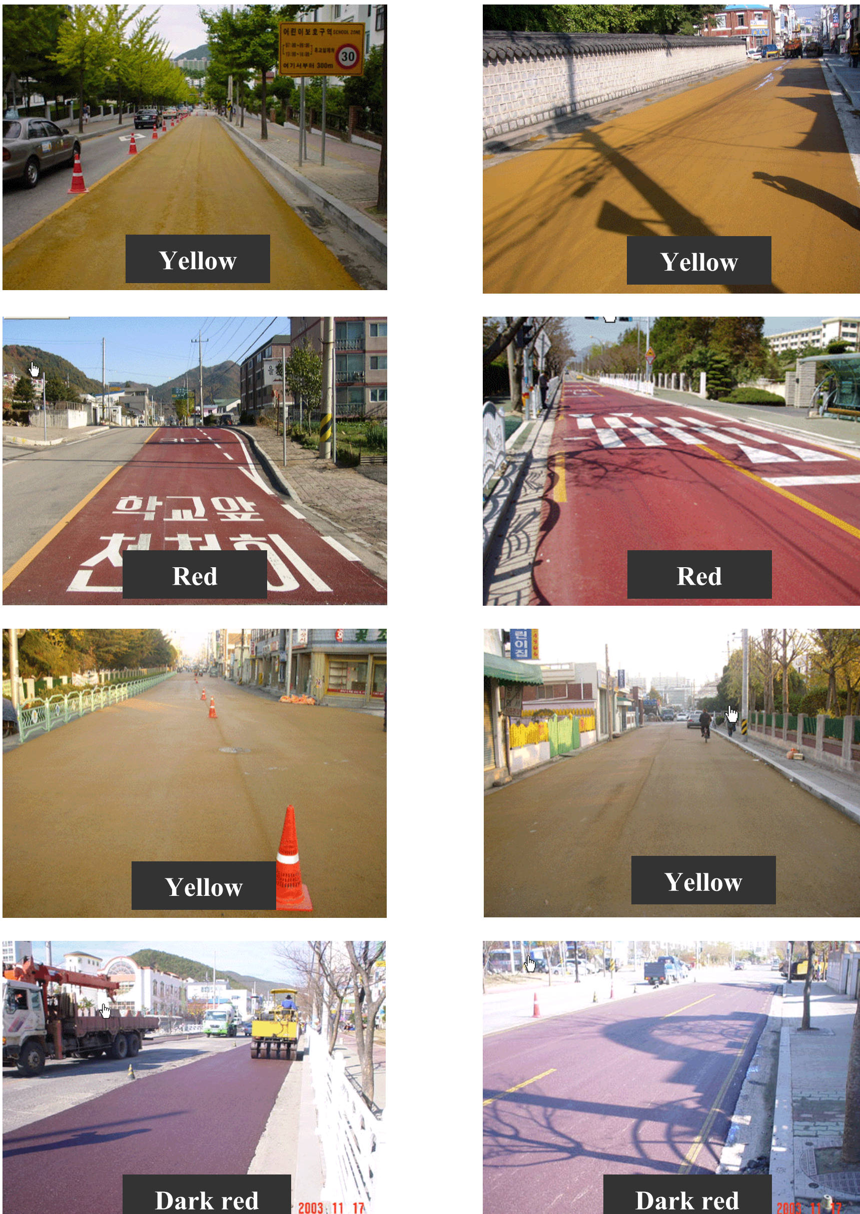


Figure 9: Field application.

3.3 Field application

G-TBL mixture (the color asphalt mix modified with 5% LDPE) has been applied to a lot of elementary school zones since 2003 (Figure 9). Until now, the results of visual investigation have showed that pavement surfaces have little rutting and cracking.

4 Conclusions

This study presented a methodology of introducing color flexible concrete pavement (CFCP) for an elementary school zone and evaluated its engineering properties through the laboratory experiments. All mixtures satisfied Marshall properties for surface course pavement for a secondary or primary road. The modification of transparent binder using LDPE was effective on increasing the tensile strength and stiffness. Wheel tracking test indicated that the CFCP modified with 5% LDPE had greater resistance against permanent deformation, compared to conventional asphalt mixture. The developed CFCP has been paved in a lot of elementary school zones in South Korea for over three years, and until now there have been few problems.

Acknowledgement

This study was supported by the Research Center for Advanced Mineral Aggregate Composites, Kangwon National University, Korea.

References

[1] http://www.onemotoring.com.sg/publish/onemotoring/en/on_the_roads/road_safety/school_zone_safety.html.

[2] Kim, K. W., Oh, S. K., Doh, Y. S. & Lee, S. H., Fundamental characteristics of polymer-modified color flexible pavement concrete. *Proc. Of 3rd Asia Symposium on Polymers in Concrete*, Tongji University, Shanghai, China, pp. 151-156, 2000.

[3] Kim, K. W., Joe, H. W., Li, X. F., Lee, J. Y. & Ahn, K. A., Evaluation of polymers (LDPE and SBS) modified asphalt mixtures. *Proc. Of '97 Advanced Technologies in Asphalt Pavements,* Research Center for Advanced Mineral Aggregate Composites, Kangwon National University, Korea, 1997.

[4] Kim, K. W., Ahn, K. A., Joe, H. W. & Li, X. F., Evaluation of tensile properties of polymer-modified asphalt concrete. *Journal of Korean Society for Civil Engineers*, Vol. 18, No. 3(1), Seoul, Korea, pp. 53-59, 1998.

[5] Kim, K. W., Li, X. F., Lee, J. Y. & Lee, S. H., Deformation control by aggregate contact increment in asphalt concrete mixture. *Journal of Korean Society for Civil Engineers*, Vol. 18, No. 3(4), Seoul, Korea, pp. 475-484, 1998.
[6] Mix design method for asphalt concrete and other hot-mix types. MS-2, 6th Ed., Asphalt Institute, Lexington, KY, 1993.