Fifth International Conference on Sustainable Construction Materials and Technologies. http://www.claisse.info/Proceedings.htm

CONSIDERATION ON APPEARANCE LIMITATIONS OF FLY ASH BLENDED WITHIN CONCRETE

Yosuke Mitani[1], Koji Takasu[2], Hidehiro Koyamada[2], Hiroki Suyama[3]
[1]1-1 Hibikino Wakamatsu-ku Kitakyushu, Fukuoka, 808-0135, Iapan,
z8mbb027@eng.kitakyu-u.ac.jp, Graduate School, The Univ. of Kitakyushu.
[2]Prof., Dr.Eng., The Univ. of Kitakyushu.
[3]Assoc. Prof., Dr.Eng., The Univ. of Kitakyushu.

ABSTRACT

In this paper, we measured the color of concrete mixed with fly ash, and examined an appearance limit of the color through psychology experiment and logistic-regression analysis. As a result, the following was clarified. It was admitted that fly ash had the effect to change color of the concrete according to its own color, and the effect to decrease lightness and metric chroma (CIELAB color space) of the concrete. It was estimated that the testee preferred the concrete recycled by-product provided that the lightness was more than -8.0 of ordinary concrete and the metric chroma was less than 6.5 of ordinary concrete. In such case, the lightness of fly ash must be more than -0.26 of OPC and the metric chroma of fly ash must be less than 0.38 of OPC, when a quarter of OPC is replaced with fly ash.

Keywords: Concrete, fly ash, metric chroma.

1. INTRODUCTION

Exposed concrete is widely utilized for not only its structural strength, durability and workability, but also for its decorativeness as a finishing material. In recent years, industrial by-products, most notably fly ash and ground granulated blast furnace slag, have been actively employed as admixtures for such concrete. This said, concrete surfaces made with such by-products tend to be shunned because of the coloration to which they are prone. And yet, no effort has been made to assess how such coloration impressionistically impacts viewers. We have earlier assessed the aesthetic impact of exposed concrete cast with cement that contains byproduct fly ash[1)]. Here, in this research, we measure the coloration imparted by adding varying proportions of fly ash to cement mixtures. Also, through psychological testing and logistic regression analysis, we attempt to quantify the perceptual impact of concrete coloration on general viewers and to derive a boundary limit for the visual acceptability of concrete containing fly ash.

2. EXPERIMENTAL OVERVIEW

2.1 Sample Overview

Sample for psychological experiments were ordinary pond land cement, tap water, sea sand, and eight kinds of fly ash. The physical properties of each are shown in Table 1.

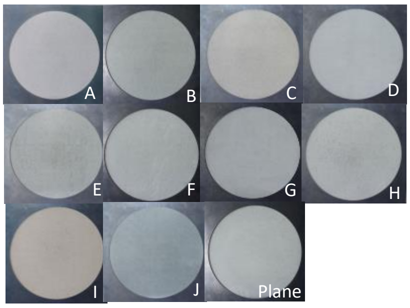
Table 1. Materials investigated of concrete samples

Type	Physical properties
Normal Portland cement	Density 3.16g/cm^3 Specific surface area 28,543cm^2/cm^3 L*=61.51, a*=-0.35, b*=8.15
Tap water	-
Sea sand	Surface dry density 2.60g/cm^3 Coarse grain ratio 2.45
Pigment（Red ,Yellow）	-
Fly ash c	Density 2.67g/cm^3 Specific surface area 38,796cm^2/cm^3 L*=51.42, a*=4.43, b*=16.34
Fly ash d	Density 2.28g/cm^3 Specific surface area 21,752cm2/cm^3 L*=64.27, a*=0.41, b*=3.67
Fly ash e	Density 2.49g/cm^3 Specific surface area27,995cm^2/cm^3 L*=40.9, a*=1.74, b*=9.65
Fly ash f	Density 2.25g/cm3 Specific surface area 27,627cm^2/cm^3 L*=67.29, a*=0.84, b*=10.47
Fly ash g	Density 2.14g/cm^3 Specific surface area 35,709cm^2/cm^3 L*=61.84, a*=1.63, b*=12.32
Fly ash h	Density 2.12g/cm^3 Specific surface area 33,908cm^2/cm^3 L*=73.51, a*=7.1, b*=20.46
Fly ash i	Density 2.33g/cm^3 Specific surface area 49,184cm^2/cm^3 L*=65.28, a*=13.9, b*=26.34
Fly ash j	Density 2.17g/cm^3 Specific surface area 19,049cm^2/cm^3 L*=43.21, a*=0.35, b*=2.05

As a preliminary survey, we poured concrete into frames lined with one of seven types of sheets, whereupon we found that a fluoro-glass sheet produces surfaces with the least overall uneven gloss. Thus, for the remainder of our survey, we utilized frames lined with such sheets. For a plain sample mixture, we utilized a mortar having a 45% water-to-cement ratio [mass ratio of 0.45 tap water : 1 ordinary Portland cement (OPC) : 2.1 sea sand]. In addition to this plain sample mixture, we prepared ten other sample mixtures. Sample A contained 1% (relative to OPC) red pigment; Sample B contained 2% yellow pigment; and Samples C through J contained fly ash c through j as a 25% substitution for OPC.

Test sample dimensions were 450 mm x 450 mm x 30 mm. The samples were prepared by pouring concrete into frames having a 12-mm-thick steel bottom plate. In previous research[1)], it was shown the surface porosity has a negative aesthetic impact. Thus, to keep pores from forming, we (1) poured concrete into frames positioned such that surfaces to be aesthetically evaluated in psychological testing were on the bottom, and (2) hammered those bottom surfaces with wooden mallets to remove any nascent pores. Poured cement was allowed to cure within the filled frames for seven days in a 20°C ambient environment. The samples were then removed from their frames and allowed to cure in air for at least 21 more days. They were subjected to testing only after confirming that their surface brightness had stabilized.

Photograph 1 shows the external appearance of the samples. Tabulated in Table 2 are brightness L* and colorations a* and b* (SCE) of samples as measured immediately before psychological testing. Shown are average values (and standard deviations) of measurements taken at 37 points on sample surfaces selected during psychological testing by means of a Konica Minolta CM-700d spectrophotometer. Relative to the coloration of OPC, we find that that brightness L* of the plain mixture sample increases (become more whitish) and that colorations a* and b* decrease (become more greenish; become less yellowish).



Photograph 1. Appearance of

Table 2. Surface condition of sample

	L*	a*	b*
Plane	67.08	-0.65	2.86
A	53.36	1.88	1.17
B	54.58	-1.15	2.96
C	49.66	0.57	4.32
D	60.19	-0.97	0.49
E	43.14	-0.25	2.35
F	62.44	-0.63	2.66
G	67.89	-0.55	2.15
H	58.71	-0.03	3.11
I	58.49	3.41	8.65
J	43.09	-0.86	-0.12

~~2.~~2 Method of Psychological Testing

Psychological testing was conducted between the Honjo Park and The University of Kitakyushu during the period from 12: 00-16: 00 on 27th October, 9: 00-16: 00 on November 10, 10: 00-15: 00 on 12th November. Sample measurement within the psychological testing revealed a surface illuminance of 2,800 to 6,840lx. One hundred evaluators (test participants; attributes tabulated in Fig. 1) participated in the survey.

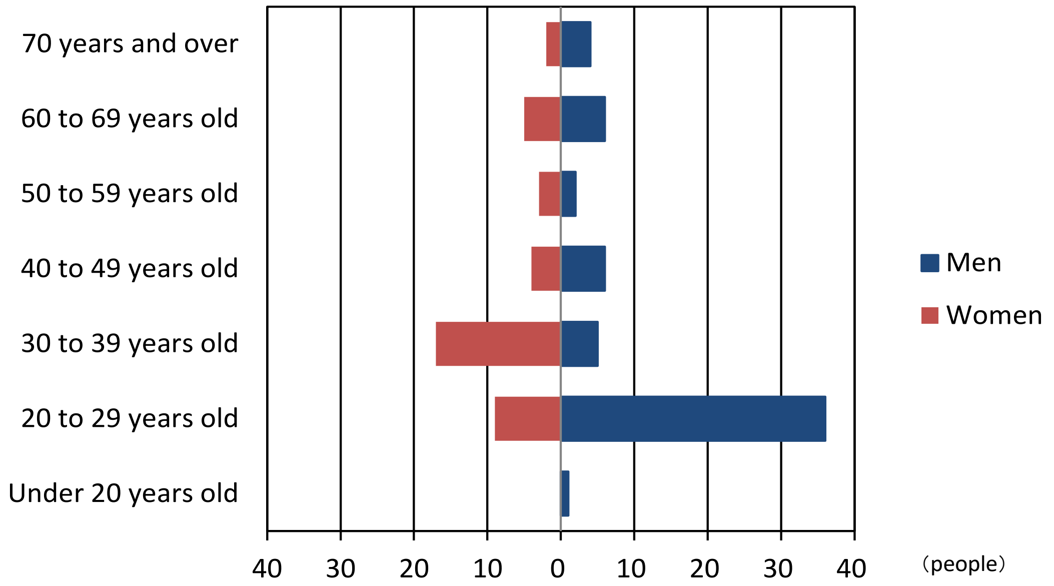


Figure 1. Attributes of subjects (N = 100)

Each test participant was simultaneously shown two samples, whereupon he or she was asked, “On the right (or left) is typical concrete, and on the left (right) is concrete that, because it contains a recycled industrial byproduct, imposes a comparatively light environmental burden. Now, which would you prefer?” Plain concrete was indicated as “typical concrete,” while recycled-byproduct-containing concretes (i.e., samples containing fly ash or pigment) were indicated as concrete samples A through J. This was done multiple times, changing the selection (changing the test sample) repeatedly until ten responses were received from each participant. Photograph 2 shows psychological testing in progress.

Photograph 2. Psychological testing situation

The samples were placed on the north side. Throughout the psychological test period, only sky light was incident on the surface of the samples. Figure 2 illustrates the manner in which the samples were shown to the participants. They were presented as 400mm discs placed at a distance of 1,500mm. Per the groundbreaking proxemics research[1), 2)] of Edward T. Hall[3)], we know that humans can see most acutely over a visual field of 12°. We designed our arrangement accordingly (specifically, we placed the samples at what would be a 10° downward angle for a person with an eye level of 1,531mm [4)]). We placed the samples at 100mm intervals.

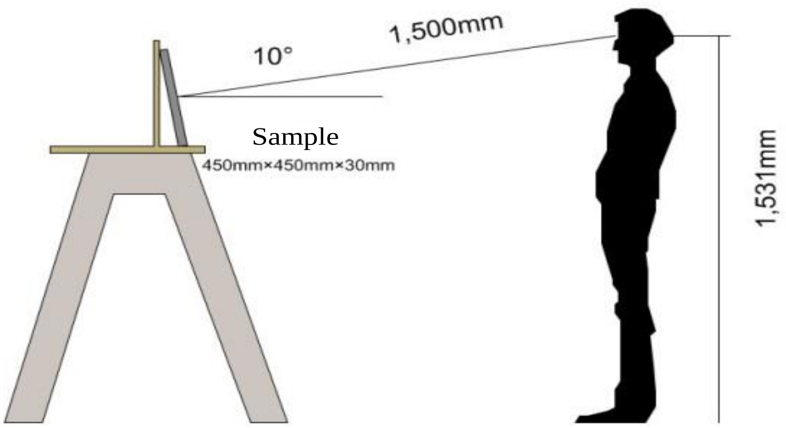


Figure 2. Presentation of specimen to the subject

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 Change in Concrete Surface Coloration upon Fly Ash Addition

As a means to estimate changes in concrete coloration (ΔL*, Δa*, Δb*) relative to plain concrete upon differing fly ash additions, we propose Equation (1), a function of OPC and fly ash coloration (L*, a*, b*), unit mass, and relative surface area. Also, as previous research[6)] has shown that aggregates have little impact on concrete surface coloration, we do not include a sea sand parameter in Equation 1. Fig. 3 presents a comparison between ΔL*, Δa*, Δb* and Δchroma (metric chroma) values as calculated with Equation 1 and actual measured values of same. In the resulting plots in the figure, we see that samples containing fly ash all fall below the x-y line for a corresponding plain sample, suggesting that fly ash not only changes concrete coloration with its own color, but also acts to lower brightness L* and colorations a* and b*.

$$\Delta L^* = \frac{\text{OPC Unit Amount} \times \text{OPC Specific surface area}}{\text{OPC Unit Amount} \times \text{OPC Specific surface area} + \text{FA Unit Amount} \times \text{FA Specific surface area}} \times \text{OPC } L^*$$

$$+ \frac{\text{FA Unit Amount} \times \text{FA Specific surface area}}{\text{OPC Unit Amount} \times \text{OPC Specific surface area} + \text{FA Unit Amount} \times \text{FA Specific surface area}} \times \text{FA } L^* - \text{OPC } L^*$$

$$= \underbrace{\boxed{\frac{\text{FA Unit Amount} \times \text{FA Specific surface area}}{\text{OPC Unit Amount} \times \text{OPC Specific surface area} + \text{FA Unit Amount} \times \text{FA Specific surface area}}}}_{\text{Coefficient } k} \times \text{FA } L^*$$

Calculate Δa *, Δb * and Δchroma as well···**Equation 1.**

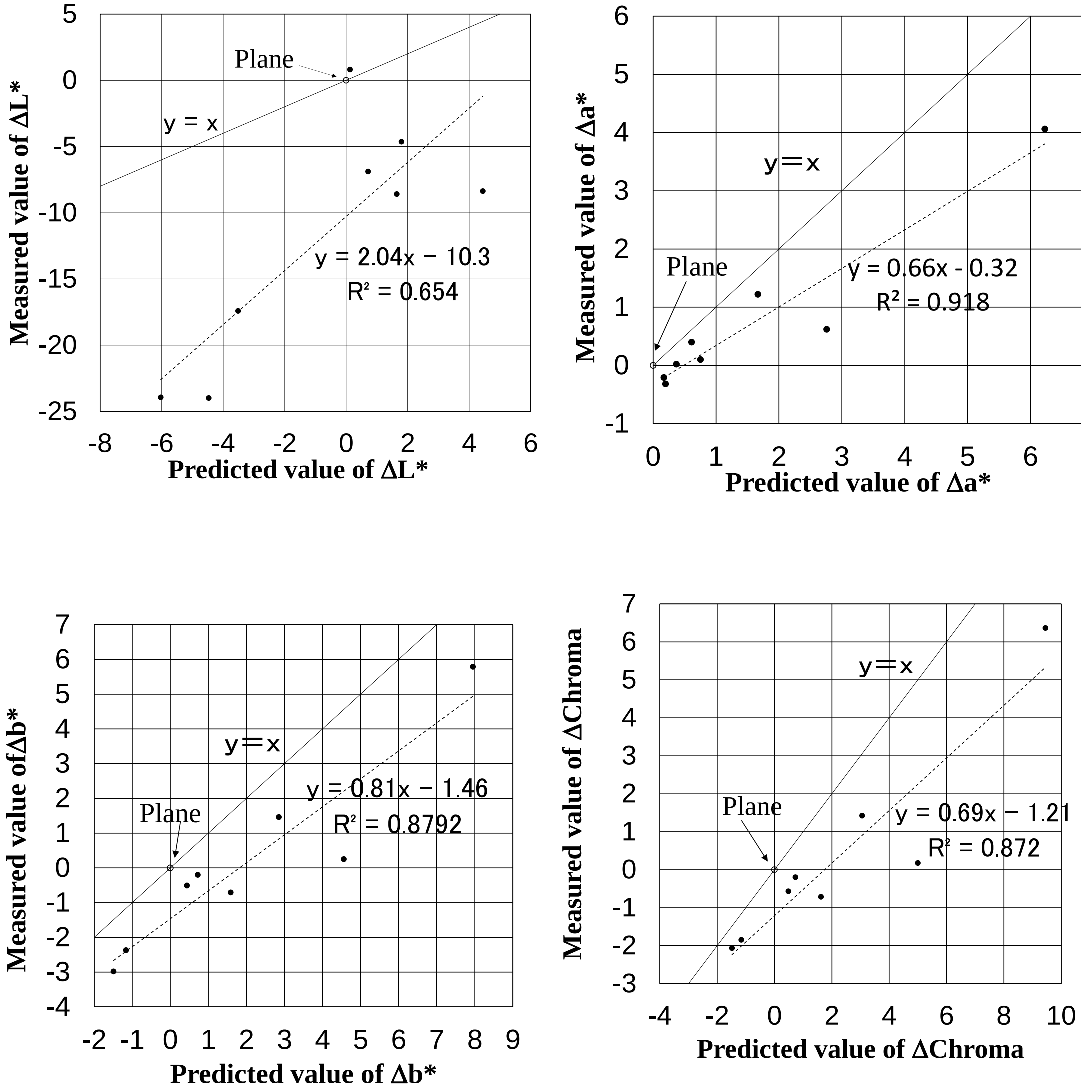


Figure 3. Relationship between the predicted value of the amount of change in color of the sample surface and the measured value

3.2 Results of Psychological Testing

Results of psychological testing are shown in Fig. 4. We note a tendency by which byproduct-containing concrete with a higher brightness L* is progressively more likely to favorably assessed, while concrete with a low brightness L* combined with a high coloration b* tends to be unfavorably assessed.

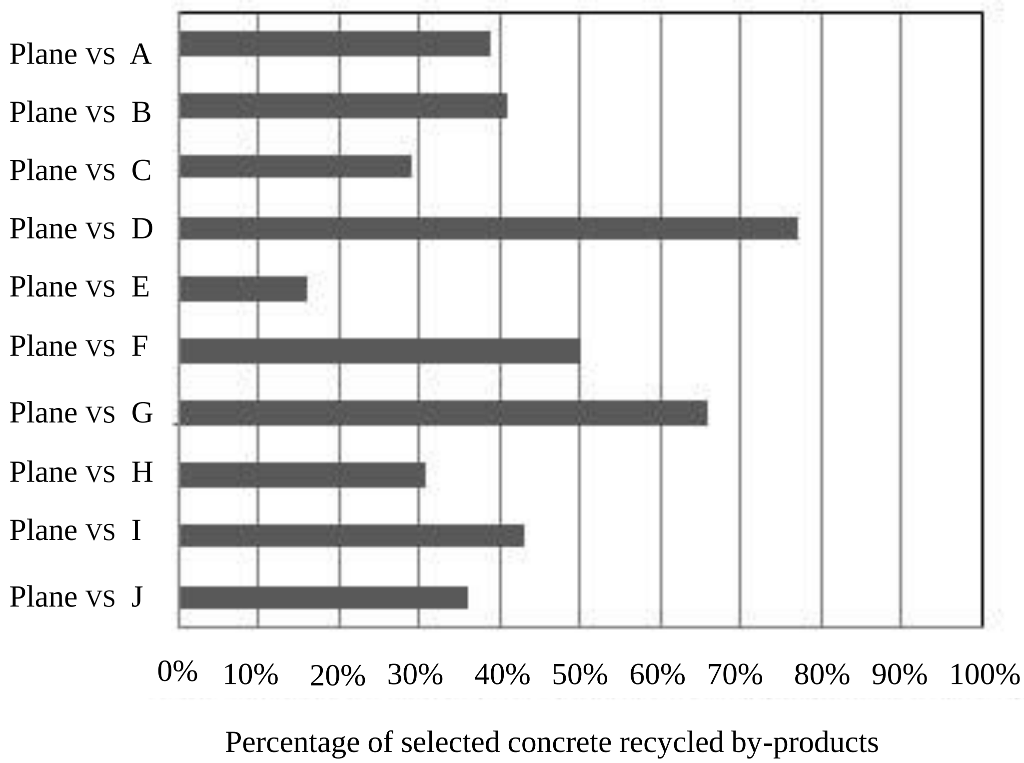


Figure 4. —Result of the questionnaire survey

3.3 Results of Logistic Regression Analysis

We conducted a binomial logistic regression within which, as a dependent variable, we take “0” to indicate a selection of a plain concrete sample by a test participant and “1” to indicate a selection of a byproduct-containing concrete sample. Changes are taken as differences (byproduct sample - plain sample) in brightness L* and in chroma between two samples evaluated by a participant. IBM SPSS Statistics 24 was used for analysis.

Forward selection method: Table 3 shows the results of binomial logistic regression with odds ratios. A chi-square test produces $p < 0.001$, which is indicative of significance. Variables ΔL* and Δchroma are significant ($p < 0.001$) covariates. A Hosmer-Lemeshow test of the regression model also produces $p < 0.001$, again indicative of significance, while the percentage of correct classifications comes out to 65.8%. From the obtained odds ratio, we infer a 0.646 probability that a test participant, upon comparing concrete samples having the same L* and chroma values under mean parameters for our research, will chose (prefer) the sample that contains recycled byproduct. Furthermore, we infer that the probability of byproduct-recycled concrete selection inverts (flips) when the brightness L* differential reaches -8.0 or when the chroma differential reaches +6.5 (Fig. 5). This suggests that in a concrete within which 25% of OPC has been replaced by fly ash (k coefficient within Equation (1) uniformly set to 0.33), it is necessary to keep the brightness L* of the fly ash to -0.26 or more relative to OPC and to keep its chroma to 0.38 or less (Fig. 6).

Table 3. The results of binomial logistic regression

	Partial regression coefficient	Significance probability (p)	Odds ratio	95% Lower limit	95% Upper limit
ΔL*	.075	< .001	1.078	1.059	1.097
ΔChroma	-.093	.002	.911	.859	.966
Constant	.602	—	1.825		

A chi-square test $p < .001$ Percentage of correct classification 65.8%

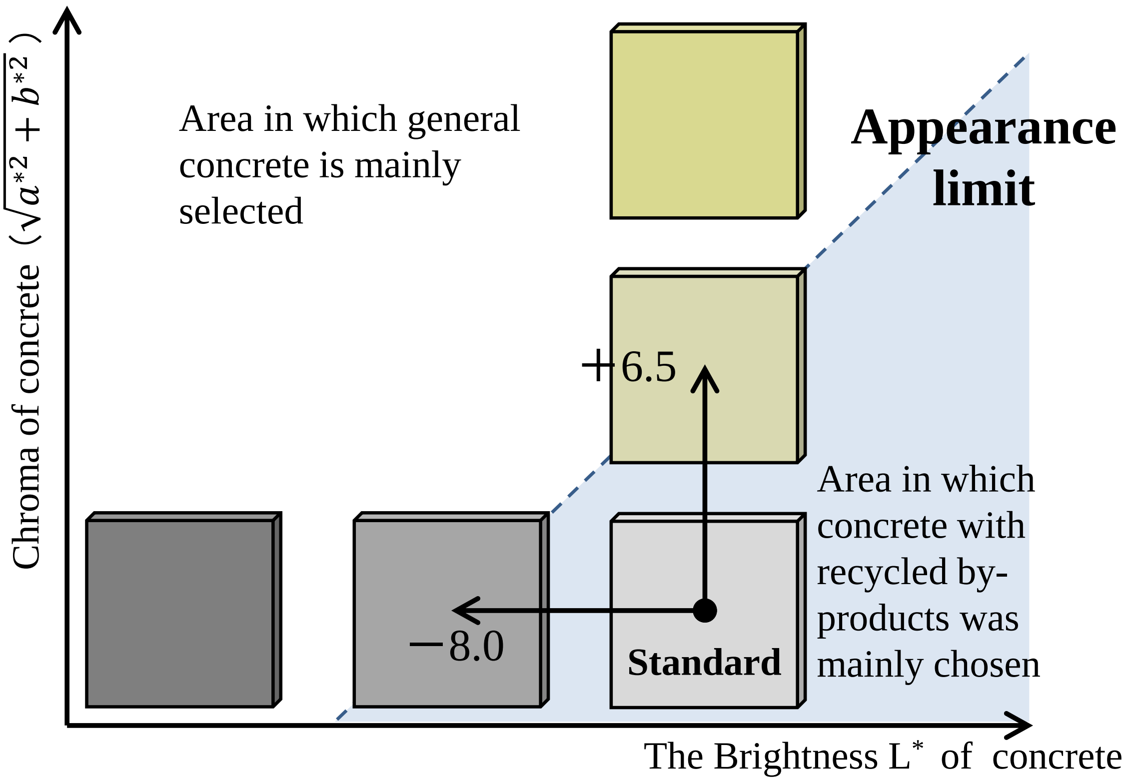


Figure 5. Area in which concrete with recycled by-products was mainly chosen

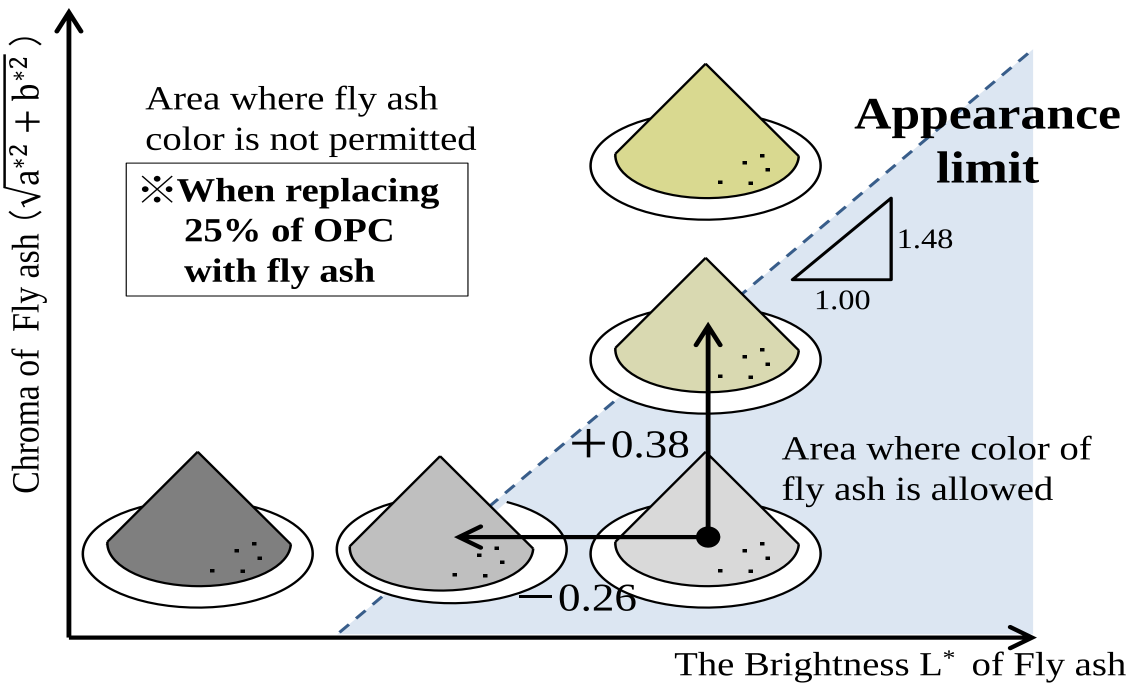


Figure 6. Tolerance range of fly ash color

4. SUMMARY

In this research, we have revealed how fly ash additions impart color to concrete. Furthermore, we conducted psychological testing in which participants were asked to assess various concrete colorations thus imparted. As a result, the following knowledge was obtained.

(1) In addition to changing the color of concrete according to its own color, FA is considered to have the effect of decreasing all of lightness L *, color a *, b *.

(2) The limit on the appearance where the by-product recycled concrete is selected is -8.0 for the lightness L * and 6.5 for the saturation difference from general concrete.

In order to satisfy this limit under the condition that 25% of ordinary Portland cement is replaced by FA, the lightness L * of the FA used is -0.26 or more as compared with ordinary Portland cement and the saturation degree is 0.38 It must be within the range which must be below.

-REFERENCES-

1) Nakayama D., Suyama H., Takasu K. and Koyamada H.: IMPRESSION EVALUATION OF CONCRETE SURFACE USING BYPRODUCTS, ASEA SEC 4 Streamlining Information Transfer between Construction and Structural Australia, 2018

2) liu lingzhi, Masuda Y, Sato Y: Evaluation of colors and properties of banged concrete and its effect on image, Cement Association, Cement · Concrete Papers Collection,No. 50,2006 (in Japan)

3) Tonuma K: Human scale 1978 (in Japan)

4) Alvin R. Tilley and Henry Dreyfuss Associates: The Measure of Man and Woman: Human Factors in Design, 2001