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IMPRESSION EVALUATION OF CONCRETE SURFACE USING BYPRODUCTS

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Cement concrete requires strength, durability, and workability. Furthermore, the appearance of concrete must be good. Recently, the concrete industry has a tendency to actively utilize byproducts, all over the world, but consumers dislike the color of concrete using byproducts. This is an obstacle to the active use of byproducts. However, it is not clearly understood how consumers make the impression to color of concrete using byproducts. Therefore, we conducted a questionnaire survey using concrete using byproducts, and analyzed the answers with factor analysis and covariance analysis. As a result, the following was clarified: (1) three factors, such as beauty, massiveness and familiarity, were extracted as a factor of exposed concrete appearance, (2) the beauty of concrete was enhanced by the whiteness of the surface and was worsened by pits and surface yellowing, (3) the massiveness of concrete was worsened by the beauty and surface whiteness, and (4) even though the subjects knew that recycled byproducts were used in concrete, the evaluation of beauty did not change.

Keywords: Psychological impact, Path analysis, Covariate structure analysis.

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 byproducts, 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 byproducts 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 (Akiyama 1992).

Lingzhi *et al.* (2007) undertook research on the impressionistic impact of exposed concrete, where test subjects assessed them by applying factor analysis. We prepared concrete samples of varying colorations by content of byproducts. Then, we surveyed test subjects to learn their impressions, applied factor analysis to extract main factors behind the impressions, and covariate structure analysis to find the impact of sample porosity, color blurring, brightness and coloration.

2 EXPERIMENT OVERVIEW

2.1 Sample Overview

2.1.1 *Materials investigated*

Materials utilized to produce exposed concrete samples for these impressionistic assessments are: normal Portland cement; tap water; sea sand; crushed stone; five classes (C through G) of fly ash;

and ground granulated blast furnace slag. Table 1 shows the brightness L* and colorations a* and b* of each of these materials, based on JIS Z 8729/CIE1976. We also added a high-performance AE (air entraining) water reducing agent to assure a suitable degree of fluidity upon pouring.

Table 1. Materials.

Concrete samples	L*	a*	b*	Density	Blaine value
Normal Portland cement	47.87	-0.48	9.79	3.16	-
fly ash C	52.71	0.99	11.71	2.21	3568.45
fly ash D	37.72	0.45	5.28	2.24	3449.11
fly ash E	52.36	0.48	12.49	2.25	3703.19
fly ash F	37.90	0.23	2.15	2.14	3802.02
fly ash G	47.23	0.35	2.83	2.28	3727.21
Ground granulated blast furnace slag	45.81	-0.17	7.60	2.31	3522.22

2.1.2 *Mixing and pouring*

We prepared nine types of exposed concrete samples for assessment. Samples A and I were made of normal concrete having a water content of 175 kg/m^3 and a water-cement ratio of 50%. Sample B is of high-strength concrete having a water-cement ratio of 40%. Samples C through G (5 samples) are comprised of an ordinary concrete base to which is added (substituted/mixed) a fly ash aggregate of, respectively, class C to G at a proportion of 120kg/m^3. And, Sample H is a concrete prepared by a 45% substitution of cement with ground granulated blast furnace slag.

Test sample dimensions were 450mm x 450mm x 30mm. The samples were prepared by pouring cement into frames fabricated with coated concrete panels, and allowed to cure for seven days. After removal, samples were cured in air for seven more days. They were subjected to impressionistic assessment only after confirming that their surface brightness had stabilized.

2.1.3 *Surface condition of the samples*

Tabulated in Table 2 are their porosity fraction, brightness L*, colorations a* and b*, and standard deviation of brightness L*. Porosity fraction was determined by first photographing sample surfaces and then measuring the proportion of pixels indicative of a pore. Because some samples exhibited much more porosity than others, we applied the Weber–Fechner approach and, in our analysis, used logarithmic values. For the measurement of brightness L* and coloration a*, we utilized a Minolta CR-300 Chroma Meter (colorimeter), with results taken as the average value of 37 measurements of each sample surface. We found the fluctuation in red-green coloration a* to be smaller than the fluctuation in either brightness L* or in yellow-blue coloration b*. All ten observers within a preliminary survey could discern a yellowing of the samples along the yellow-blue balance but none could detect any change in the red-green balance. We thus decided to exclude red-green coloration a* as an item for analysis under this study.

2.2 Survey Overview

2.2.1 *Query items*

We next conducted a survey to assess the psychological/impressionistic impact of each of the nine types of exposed concrete samples. Here, we turn to a set of 18 adjectival pairs utilized in previous research. We assessed the results by means of the semantic differential method, grading each over seven levels ranging from -3 to +3. Query items are listed in their entirety in Table 3.

Table 2. Sample surfaces.

Concrete samples	Porosity fraction	L*	a*	b*	Standard deviation of brightness L*
A	1.794	67.54	-0.77	3.56	2.02
B	0.003	70.11	-0.69	4.48	0.84
C	0.152	70.44	-0.39	5.38	1.10
D	0.079	62.48	-0.66	1.20	0.84
E	0.068	72.28	-0.64	3.56	0.85
F	0.230	62.35	-0.81	1.44	1.02
G	0.206	66.87	-0.82	1.46	4.63
H	0.742	74.56	-0.58	3.47	1.43
I	0.273	68.39	-0.43	4.75	2.20

Table 3. Query items.

No.	Queryitems are listed in their entirety
A01	Coarse⇔Smooth
A02	Sober ⇔Flashy
A03	Heavy⇔Light
A04	Bright⇔Dark
A05	Loose⇔Moist
A06	Clean⇔Dirty
A07	Plain⇔ Special
A08	Rich⇔Poor
A09	Quiet⇔Active
A10	Hot⇔Cool
A11	Shiny⇔Dull
A12	Like⇔Hate
A13	Concrete⇔Not-concrete
A14	Supernatural⇔Artificial
A15	Hard⇔Soft
A16	Beautiful⇔Ugly
A17	Mannish⇔Woman
A18	Airy⇔ Substantial

2.2.2 *Implementing institution, survey participant affiliations*

We surveyed 200 participants (i.e., N = 200) over 7-13 November 2015. Participant affiliations are tabulated within Figure 1. We divided the participants into two equal groups, one for which we presented a detailed written explanation of survey questions (N = 100), and one for which we presented no explanation (N = 100). The verbiage on the questionnaire sheet for the first (detailed explanation) group is as below:

Samples A, I: Ordinary concrete: typically used for buildings and other structures.

Sample B: High-strength concrete: reinforced concrete with additional cement.

Samples C through G: Fly-ash concrete, containing fly ash in addition to cement (fly ash is a byproduct of combustion at coal-fired electric power plants).

Sample H: Blast furnace slag concrete, containing ground granulated blast furnace slag in addition to cement (blast furnace slag is a byproduct of the iron-making process at steelworks).

2.2.3 *Method of sample presentation*

The survey was conducted on a wooden deck. The samples were illuminated with only natural outdoor light (a MODEL LX-105 digital light meter (CUSTOM Corporation) indicated a surface illuminance of 960 to 3,118x). Figure 1 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 of Edward T. Hall, 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, typical for the 20- to 24-year-old Japanese men and women recruited for the test. We placed the samples at 100mm intervals on a dark cloth background so as to prevent anything else from entering the participants' field of vision.

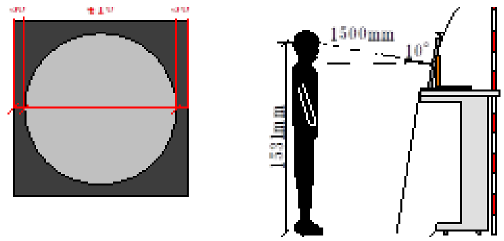

Figure 1. The manner in which the samples were shown to the participants.

2.2.4 *Analysis method*

We utilized IBM SPSS Statistics 22.0 and IBM SPSS Amos 23 (a structural equation modeling (SEM) program) to analyze the survey results.

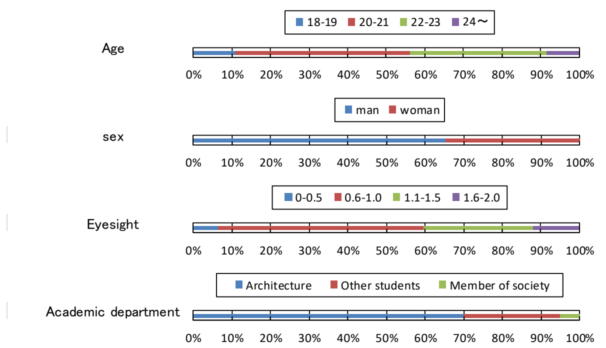

Figure 2. Survey participant affiliations.

3 SURVEY OVERVIEW

3.1 Factors Comprising the Impressionistic Impact of Concrete

With results obtained with the 18 adjectival pairs, we conducted factor analysis by means of the maximum likelihood method. Changes in eigenvalue were: 5.80, 1.85, 1.56, 1.30, 1.00…. We hypothesized three factor structures (upon consideration of the number of queries) and once again conducted a factor analysis, this time with the maximum likelihood method / promax rotation. We excluded four pairs not having a sufficient factor loading (0.35 minimum) and, by this, arrived at the factor pattern of Table 4.

The first factor comprises six pairs and, at a contribution rate of 39.2%, accounts for a large portion of the total. We consider this factor – "appearance"– to be the most important and note high factor loadings in such appearance-related pairs as beautiful/ugly, like/hate and clean/dirty.

The second factor is comprised of five pairs and shows high factor loadings in such texture-related pairs as heavy/light and airy/substantial. We refer to this factor as "presence."

The third factor is comprised of three pairs and shows high factor loadings in perceptions generally considered contrasting to typical concrete, including plain/special and subdued/active. We refer to this factor as "familiarity." Correlations are shown in Table 5.

3.2 Impact of Concrete Surface Condition on Viewer Impressions

To examine the effect of porosity, color blurring, brightness L* and coloration b*on each of the above three factors, we carried out a path analysis under covariate structure analysis.

Table 4. Pattern matrix.

No.	Adjectival pairs	FactorI	FactorII	FactorIII
A16	Beautiful⇔Ugly	0.884	0.036	0.002
A12	Like⇔Hate	0.842	0.194	-0.024
A06	Clean⇔Dirty	0.769	-0.097	0.151
A08	Rich⇔Poor	0.610	0.065	-0.282
A01	Coarse⇔Smooth	-0.550	0.214	-0.173
A11	Shiny⇔Dull	0.516	-0.139	-0.060
A03	Heavy⇔Light	0.125	0.878	0.020
A18	Airy⇔ Substantial	-0.007	-0.749	0.108
A17	Mannish⇔Woman	-0.136	0.672	-0.104
A04	Bright⇔Dark	0.167	-0.632	-0.041
A15	Hard⇔Soft	0.122	0.523	0.045
A07	Plain⇔ Special	-0153	-0.150	0.541
A09	Quiet⇔Active	0.301	0.083	0.526
A02	Sober ⇔Flashy	-0.222	0.347	0.508
Eigenvalue		5.49	1.64	1.44
Contribution rate		39.2%	50.9%	61.2%
Factor's name		Appearance	Presence	Familiarity

Table 5. Factor correlation matrix.

Factor	I	II	III
Appearance	1.000	-.646	.090
Presence		1.000	.010
Familiarity			1.000

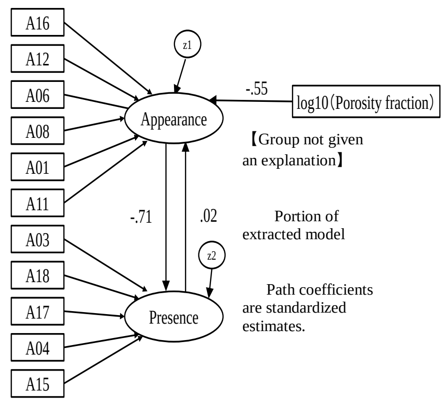

Figure 3. Measurement model for "appearance" and "presence".

We consider the cause and effect relation among the three factors (i.e., appearance, presence and familiarity). Under assumptions that (a) appearance and presence have some influence on each other and (b) porosity has an influence on only appearance, we analyzed questionnaire results from the group to which we did not present a preliminary explanation (Figure 3). We found that the path from presence to appearance does not have significance ($p = .853$). By this, we learn that although appearance does have a negatively impact on presence, presence does not have a significant impact on appearance.

We hypothesized the cause-and-effect relationships among the three factors to be only that appearance has an impact on weightiness /presence. We also assume that color blurring on the surface sample (standard deviation of L*), brightness L* and coloration b* have an impact on the three factors. We analyze results from the group to which no explanation was presented. We find that the path from color blurring to presence is significant ($p = .018$), as are the paths from color blurring to familiarity ($p =.393$), from brightness L* to familiarity ($p =.370$), and from coloration b* to familiarity ($p = .374$). We thus eliminate the paths found to be not significant (leaving us with paths for which $p < .001$) and, this time adding questionnaire data from the group to which an explanation was presented. This brings us to Figure 4, our final model, from which we have that $\chi 2 = 1078.845$, df = 166, $p< 0.01$, GFI=.918, AGFI=.881, and RMSEA=.055. From this figure, we find that concrete whiteness (magnitude of brightness L*) acts to enhance appearance, whereas concrete yellowness (magnitude of coloration b*) detracts from it. Also, none of the concrete surface related variables shows a significant path to familiarity.

3.3 Bias to Impressionistic Assessments by Awareness of Byproduct Presence

We also utilized this model to evaluate how an awareness of byproduct utilization within a concrete biases viewers' impressionistic assessments of that concrete. Here, we conducted path analysis for both groups (those given an explanation, and those not) under a hypothesis that the addition of a byproduct does have an effect on concrete appearance (Figure 5). We find that with regards to the group given no explanation, the path from "use of byproduct" to "appearance" is not significant (p = .062). This is to be expected, because the respondents did not know that some byproduct was added to the cement during its preparation. This said, there was also no significant path from "use of byproduct" to "appearance" even with regards to the group given an explanation (p = .459). To put it another way, viewer assessments of concrete appearance are almost entirely the same whether or not those viewers know that some byproduct was added to the concrete during its preparation.

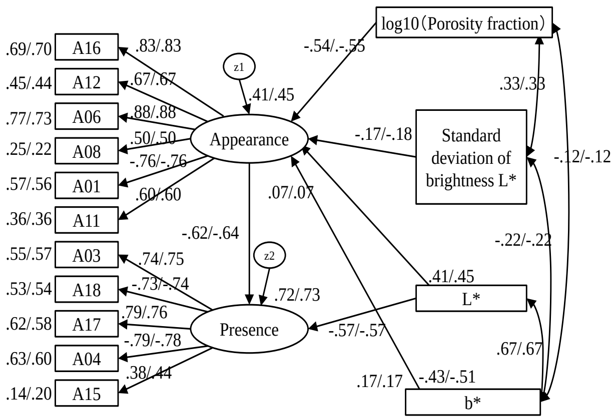

Figure 4. Formation model for exposed concrete appearance and presence.

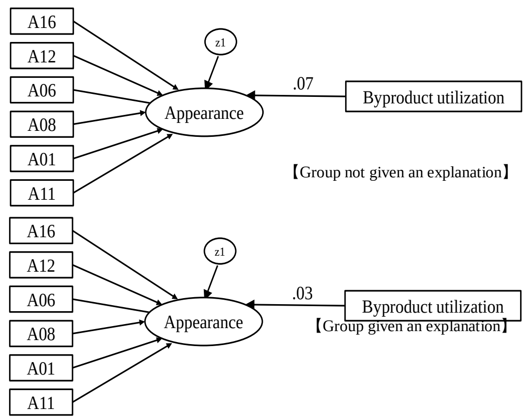

Figure 5. Measurement model for "use of byproduct" and "appearance".

4 CONCLUSIONS

This paper described how we first prepared samples of exposed concrete of differing colorations by varying the content of industrial byproducts within them. Then, with these samples, we surveyed test subjects to learn their impressions of them. We next subjected the results to factor analysis to extract the main factors behind such impressions and, from there, to covariate structure analysis.

As factors to impressionistic assessments of exposed concrete, we were able to extract "appearance," "presence" and "familiarity." Although the appearance of exposed does have a negative impact on presence, presence does not have a significant impact on appearance. Exposed concrete whiteness acts to enhance appearance, whereas yellowness detracts from it.

Viewer assessments of the appearance of exposed concrete are almost entirely the same, whether or not those viewers know that a byproduct was added to concrete during its preparation.

Acknowledgments

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