innovations. Researchers[13,14] also mentioned that there is 'lack of fit' to farming situation and 'functional gaps' in technologies spawned in the laboratories.

It can be summed up that literature on adoption has been focusing mostly on the socio-psychological characters and their influence on adoption. The socio-psychological characters, such as knowledge, economic motivation, attitude, extension agency contact, mass media exposure, milk production and sales are dynamic and subject to change. Thus, increasing the exposure to technologies through extension agencies and mass media may have an impact on knowledge and increase the adoption. Further, technology generators need to focus on improving technology in terms of performance, ease of use and fit for farming situations. Also, there is research gap in understanding the relationship between dairy innovation attributes and adoption, which needs to be addressed.

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ACKNOWLEDGEMENT. We thank the Tamil Nadu Veterinary and Animal Sciences University, Chennai for supporting the study.

Received 16 November 2015; revised accepted 12 May 2016

doi: 10.18520/cs/v111/i7/1231-1234

Surface treatment of the Secretariat Building, Chandigarh, India using selected concrete sealers for protection from environmental deterioration

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The Secretariat Building is located inside the Chandigarh, Capitol Complex, India. The exterior surface of the building has deteriorated due to weathering effects. The aim of the present study was to assess efficacy of selected protective materials on exposed heritage reinforced concrete surface of the Secretariat Building for restoration. Selected concrete sealers and Evercrete DPS with essential oil of peppermint and eucalyptus were evaluated for UV degradation yellowing test on white cement panels, accelerated ageing test on concrete beams up to 5 years, field trial on the exterior surface of the Secretariat Building up to 38 weeks and test for determining the water absorption on concrete cores (ASTM D 6489-99) up to 4 years. The result reveals that Konex WRA-2318 and La Shield WR Xtra are effective for surface treatment of the Secretariat Building without changing the colour of the surface up to 4 and 2 years respectively.

Keywords: Accelerated ageing, concrete sealer, environmental deterioration, heritage buildings, water absorption.

THE Secretariat Building, Chandigarh, India, built in 1953, was designed by noted architect Le Corbusier. It is part of the heritage Chandigarh Capitol Complex comprising three buildings – Legislative Assembly, Secretariat and High Court. The heritage building monuments in any country are mute testaments of its glorious past. However, they require regular repair and maintenance[1]. Restoration of heritage buildings involves preserving the existing appearance of a place and prevent deterioration[2]. Moisture plays an important role in most damage processes in concrete structures, such as frost damage and reinforcement corrosion. Many water-repellent agents such as silane and siloxane have shown to give a good protection against moisture and chloride ingress, thereby prolonging the service life of the concrete structure[3]. Natural factors like air, water, climate, wind, humidity and rain are the prime sources for degradation of the heritage structures. Water through capillary action enters and reduces the strength of concrete, thereby making it susceptible to corrosion[4]. The exterior surface of the Secretariat Building, was found to bio-deteriorated due to environmental conditions. Application of water-repellent agents

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based on silicon technology has been the preferred method for building surfaces against moisture entry and weathering, thereby increasing their service life[5].

Commercially available concrete sealers are based on silicon, silane, silicate, siliconate, acrylic, epoxy, urethane, etc.[6–8]. Silicon-coated kutcha bricks were reported to remain dry and did not suffer any surface damage up to 6 h of constant water spray[9]. In another study, hydroxylated silica was treated with organosilanes and silazane, and water adsorption isotherms were monitored on the resulting products[10]. The monomeric alkyl alkoxy silanes were found to be excellent water-proofing agents and only a negligible amount of sealant was lost as a result of evaporation[11]. Silicate, epoxy-phenolic and polyurethane coatings have been developed for buildings[12]. Two sodium silicate-based waterproofing formulations have also been developed for use in masonry works and concrete roof[13]. The concrete sealers or coatings can protect the bridge concrete structure from damage caused by aggressive environmental and chemical exposure[14]. A combination of 'silane + siloxane' primer with an acrylic top coat was the most effective treatment for corrosion resistance of reinforced concrete. No single coating could improve the resistance of concrete to all types of deterioration[15]. Powdered additives composed of silane/siloxane blend based on an inorganic carrier were good water repellents, once set[5]. The retarding effect of organosilanes water-soluble zycosil and zycofil on water vapour diffusion through poplar wood was evaluated. The results showed that both coating materials decreased the water vapour diffusion rate through the wood[16]. The modern methods to waterproofing rehabilitation for building infrastructure have been summarized earlier[17]. Three concrete sealers, two crack sealants and two water-repellents were evaluated under accelerated condition. The epoxy-based sealer T48CS and water-repellent ATS-42 exhibited best performance in protecting the concrete from salt scaling and showed the highest resistance to abrasion and generally lower water absorption rates and gas permeability coefficients. The results suggest that high resistance to both gas and water penetration is a crucial property in a good surface sealer, crack sealant or water-repellent applied to concrete[18]. The chloride penetration resistance was investigated using a silane-based sealer (SS1), an acrylic-based coating (AC1) and two cementitious coatings (CC1 and CC2) on concrete surface. The acrylic-based coating was found to be best, whereas cementitious coating CC1 showed the worst performance[19].

In our previous study, selected protective materials [Liquid Sealer LS-S (LS), Magik impregnator (M), WEB-CBX (W), RIK-SEAL Medium Gloss (R), Konex WRA-2318 (K), Evercrete DPS (E), La Shield WR Xtra (LG)], Evercrete DPS with essential oil of peppermint (EP) and eucalyptus (EE) were evaluated for their antifungal activity against few building fungi[20]. The present communication deals with the evaluation of the above protective materials for UV degradation yellowing test on white cement panels, accelerated ageing test on concrete beams, field trial on the exterior surface of the Secretariat Building and test for determining water absorption on concrete cores. The criteria with regard to suitable protective materials for restoration of the Secretariat Building are also presented.

The Secretariat Building is located inside the Chandigarh Capitol Complex which is set against the backdrop of the Shivalik Hills (lat. 30°44′14″N, long. 76°47′14″E). It is a long, horizontal concrete slab – 254 m long and 42 m high (Figure 1). It is more than 60 years old; the exterior surface is chemically stable and its surface porosity is also fully developed. The external concrete surface of the Secretariat Building is dirty, carbonated, stained by chemicals/environment and also bio-deteriorated.

Chandigarh has an extreme climate with hot summers and chilly winters (destructive freeze/thaw cycles). There is variation in relative humidity throughout the year. Data were collected from World Meteorological Organization for weathering conditions in Chandigarh throughout the year[21] (Table 1).

Table 2 presents details of selected concrete sealers. Concrete sealers were applied for two coats; the second coat was applied 24 h after the first coat. The essential oils were isolated using methods reported in the literature[20,22].

UV degradation and non-yellowing test was carried out on white cement panels[23] (Figure 2). The panels were treated with concrete sealers using the method of Verma and Devi[20]. Coated panels were exposed in a UV test chamber (Atlas) for 336 h (2 weeks) with a test cycle consisting of alternating periods of 8 h UV radiation at 60°C (140°F) and 4 h condensation at 50°C (122°F) (Figure 3)[24].

The concrete sealers were coated on the concrete beams ($250 \times 100 \times 100$ mm^3) in triplicate and incubated in BOD incubator at selected conditions (Table 3) to check the weathering effect on concrete sealer vis-à-vis the weather conditions of Chandigarh[21,25]. Observations were recorded up to completion of all season cycles of five years. On the basis of data collected for weather conditions in Chandigarh, test temperature and relative humidity as given in Table 3 were selected for accelerated ageing test.

The field trial was performed on the exterior exposed surface of the Secretariat Building. A site at the ground level which remained moist for a long period of time was selected for the field trial. After surface preparation, the selected concrete sealers were applied on the surface area of 300×300 mm^2. A control area was also maintained with same dimensions for comparison. The coated surface was compared for any deterioration or destruction in appearance on the treated surface due to temperature, relative humidity, air, wind, rain and UV radiation up to 38 weeks.

Table 1. Weathering conditions in Chandigarh throughout the year

Month	Temperature (°C) (maximum–minimum)	Relative humidity (%)	Month	Temperature (°C) (maximum–minimum)	Relative humidity (%)
January	19.4–3.9	80	July	35.0–24.0	79
February	21.1–5.4	76	August	32.8–22.3	84
March	29.5–10.4	66	September	29.1–20.8	81
April	34.5–14.9	48	October	28.8–16.0	71
May	42.4–28.2	45	November	19.9–9.5	69
June	44.3–30.9	62	December	18.1–4.7	78

Source: World Meteorological Organization[21].

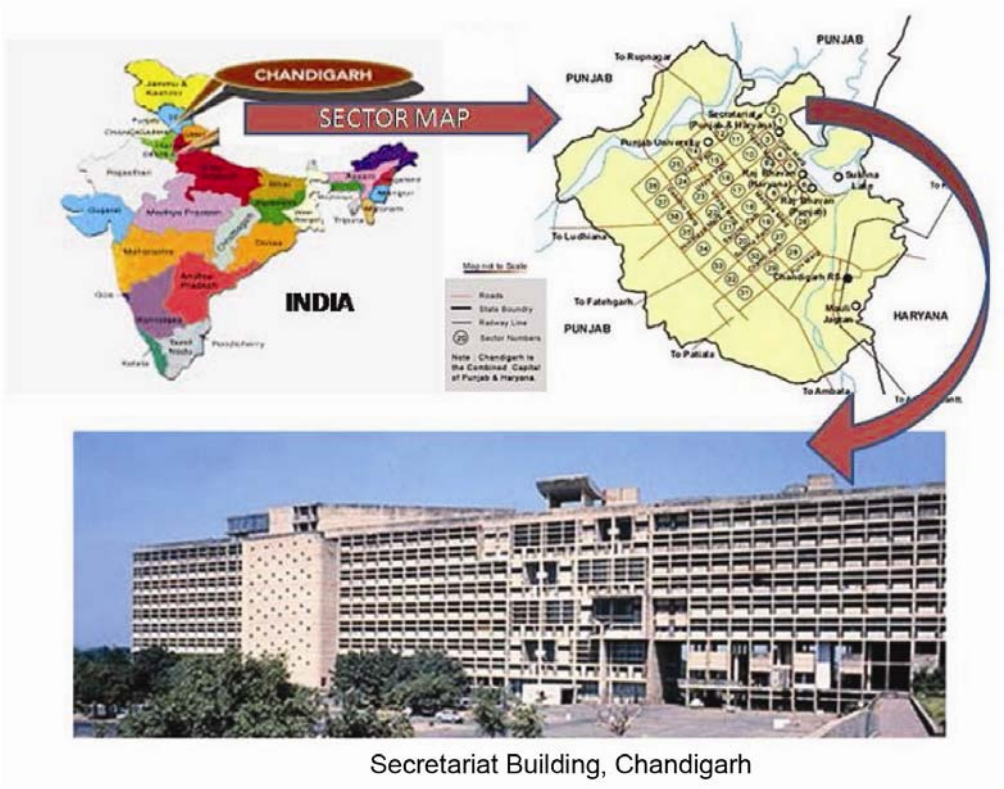

Figure 1. Location and external view of the Secretariat Building, Chandigarh, India.

Water absorption on the hardened concrete cores was performed in triplicate[26] (Figure 4). The specimens were prepared with water : cement ratio of 0.35. The diameter and length of concrete cores were 100 and 50 mm respectively. For the present study, 24-month-old concrete cores were selected. All the coated specimens were incubated in BOD incubator at the selected conditions (temperature and relative humidity) stipulated in Table 3. The observations were recorded up to completion of all season cycles of four years[27].

The percentage of water absorbed by each sample was determined as

$$\text{Absorption after immersion (\%)} = \frac{100 \times (W_2 - W_1)}{W_A},$$

where W_A is the mass of dried sample, W_1 the mass of coated sample and W_2 is the mass of sample after immersion in water.

The grading for visual observations was rated by following visual rating scale for surface deterioration after accelerated ageing and field trials (Table 4).

The colour change on white cement panels was graded by comparing with Gardner colour chart (Figure 5). The white cement panels coated with Magik impregnator, WEB-CBX, Konex WRA-2318, Evercrete DPS, Evercrete DPS with eucalyptus oil, Evercrete DPS with peppermint oil and La Shield WR Xtra did not turn yellow after UV degradation and yellowing resistance test. However, white cement panel coated with Liquid Sealer LS-S turned cream in colour after the test, while the panel coated with RIK-SEAL Medium Gloss turned ivory-yellow.

Table 2. Selected concrete sealers with main chemical base, specific features and symbols

Chemical base	Specific features	Dilution	Code
Silane	UV stable Maintains natural appearance	Liquid Sealer LS-S (diluted 10 times with thinner)	LS
Silane	Water repellent Antifungal	WEB-CBX	W
Silane	Clear appearance Antifungal Reduces water ingress	La Shield WR Xtra	LG
Silane/siloxane	Reduces water permeability Prohibits fungal growth and foul smell Clear appearance	Konex WRA-2318 (diluted 14 times with RO water)	K
Acrylic	UV-resistant Block penetration of dust, oil and chemicals	RIK-SEAL Medium Gloss	R
Acrylic	Excellent stain-proof property UV-stable Transparent Good resistance against atmospheric conditions	Magik impregnator	M
Silicate	Penetrates up to 3 cm Protects against chloride ion ingress Anti-carbonation coating Clear appearance	Evercrete DPS	E
Silicate	Penetrates up to 3 cm Protects against chloride ion ingress Anti-carbonation coating Antifungal Clear appearance	Evercrete DPS with essential oil of eucalyptus	EE
Silicate	Penetrates up to 3 cm Protects against chloride ion ingress Anti-carbonation coating Antifungal	Evercrete DPS mixed with essential oil of peppermint	EP

Figure 2. White cement panels for UV test.

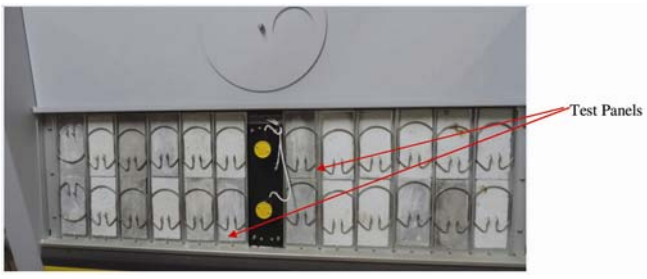

Figure 3. Test panels in the UV test chamber.

Visual observations were recorded for any deterioration on the concrete beams. Figure 6 shows the deterioration rating for 1 to 5 years. The concrete beam surfaces

Figure 4. Concrete cores immersed in water up to 48 h (ASTM D 6489-99).

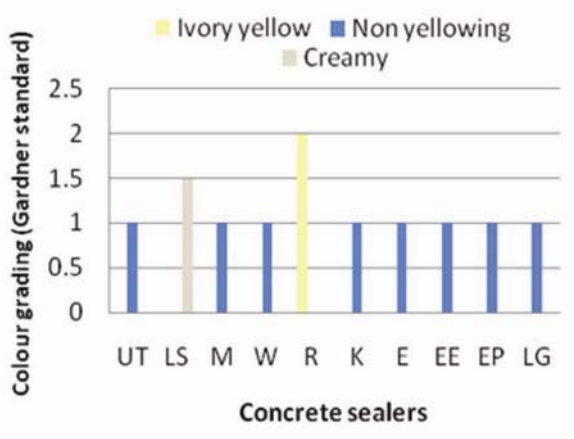

Figure 5. Gardner colour grading after UV exposure on coated white cement panels. UT, Untreated.

Table 3. Selected experimental test conditions

Season	Month	Average temperature (°C)	Selected temperature (°C)	Selected relative humidity (%)	Selected time period (h)
Spring	February end to early April	Maximum – 20 Minimum – 10	18	76	168
Summer	Mid-April to June end	Maximum – 44 Minimum – 30	45	60	168
Monsoon	Early July to mid-September	Maximum – 20 Minimum – 35	35	85	168
Autumn	September end to mid-November	Maximum – 10 Minimum – 22	22	81	168
Winter	November end to February end	Maximum – 14 Minimum – 1	10	78	168

Table 4. Visual rating scale for surface deterioration

Scale	Observation	Characteristics
0	No deterioration	No change in appearance
1	Light deterioration	Slight change in colour
2	Moderate deterioration	Appearance of dull spots and formation of bubbles
3	Heavy deterioration	Loss of glossy appearance, slight precipitation of concrete sealer, surface becomes dark
4	Failure	Appearance of dull spots, colour becomes dark, heavy precipitation of sealer on the surface

treated with Konex WRA-2318, La Shield WR Xtra and Evercrete DPS with eucalyptus oil concrete sealers and control did not change their colour after treatment up to 5 years. The concrete surface treated with Magik impregnator exhibited slight change in colour in the form of white colour film. Concrete surface treated with Evercrete DPS with peppermint oil showed slight to moderate change in colour. However, the concrete surface treated with Liquid Sealer LS-S, WEB-CBX, RIK-SEAL Medium Gloss showed significant change in colour (became darker) and lost glossy appearance due to heavy deterioration or failure after initial coating. The heavy precipitation of sealers and appearance of dull spots can be clearly visualized on the surface of the beams. The concrete beam coated with Magik impregnator, Evercrete DPS and peppermint oil showed light deterioration and slight change in colour. The beam treated with Konex WRA-2318, Evercrete DPS with eucalyptus oil and La Shield WR Xtra did not show any deterioration. The order of visual appearance wise concrete sealers for protection was found as follows: Konex WRA-2318 > Evercrete DPS with eucalyptus oil > La Shield WR Xtra > Magik impregnator > Evercrete DPS > Evercrete DPS with peppermint oil > WEB-CBX > RIK-SEAL Medium Gloss > Liquid Sealer LS-S.

The coated surface of the Secretariat Building was compared for any deterioration or destruction on treated surface due to natural factors like temperature, relative humidity, air, rain, wind and UV radiation up to 38 weeks. Figure 7 shows the deterioration rating on coated surfaces. The surface area treated with Konex WRA-2318, Evercrete DPS with eucalyptus oil, La Shield WR Xtra and control surface area exhibited no colour change. However, in the case of Magik impregnator and Evercrete DPS, slight colour change and light deterioration were seen, while in the case of Liquid Sealer LS-S and Evercrete DPS with peppermint oil moderate deterioration was observed. The surface treated with WEB-CBX and RIK-SEAL Medium Gloss showed darkest colour and heavy deterioration. The order of visual appearance wise concrete sealers for protection was found as follows: Konex WRA-2318 > Evercrete DPS with eucalyptus oil > La Shield WR Xtra > Magik impregnator > Evercrete DPS > Evercrete DPS with peppermint oil > Liquid Sealer LS-S > WEB-CBX > RIK-SEAL Medium Gloss.

The mean water absorption was recorded up to completion of all season cycles of four years (Figure 8). A widely accepted water penetration resistance criterion does not exist in case of surface-treated concretes[28]. A study[27] recommends acceptance of surface treatments which reduce water absorption by 50%. In the present study, effective concrete sealers show ≤50% water absorption compared to untreated concrete cores[27]. The untreated cores exhibit 2.40% water absorption throughout the study period. The concrete cores treated with 14 times diluted Konex WRA-2318 initially exhibited water absorption 0.63%. Absorption was recorded as 0.80%, 0.87%, 0.96% and 1.17% after 1, 2, 3 and 4 years respectively. The durability of 14 times diluted Konex WRA-2318 was recorded 4 years for protection. The concrete core treated with La Shield WR Xtra exhibited water absorption of 1.13%, 1.16%, 1.20%, 1.30% and 1.38% after initial, 1, 2, 3 and 4 years respectively. The water absorption drastically increased to 1.30% after 2 years.

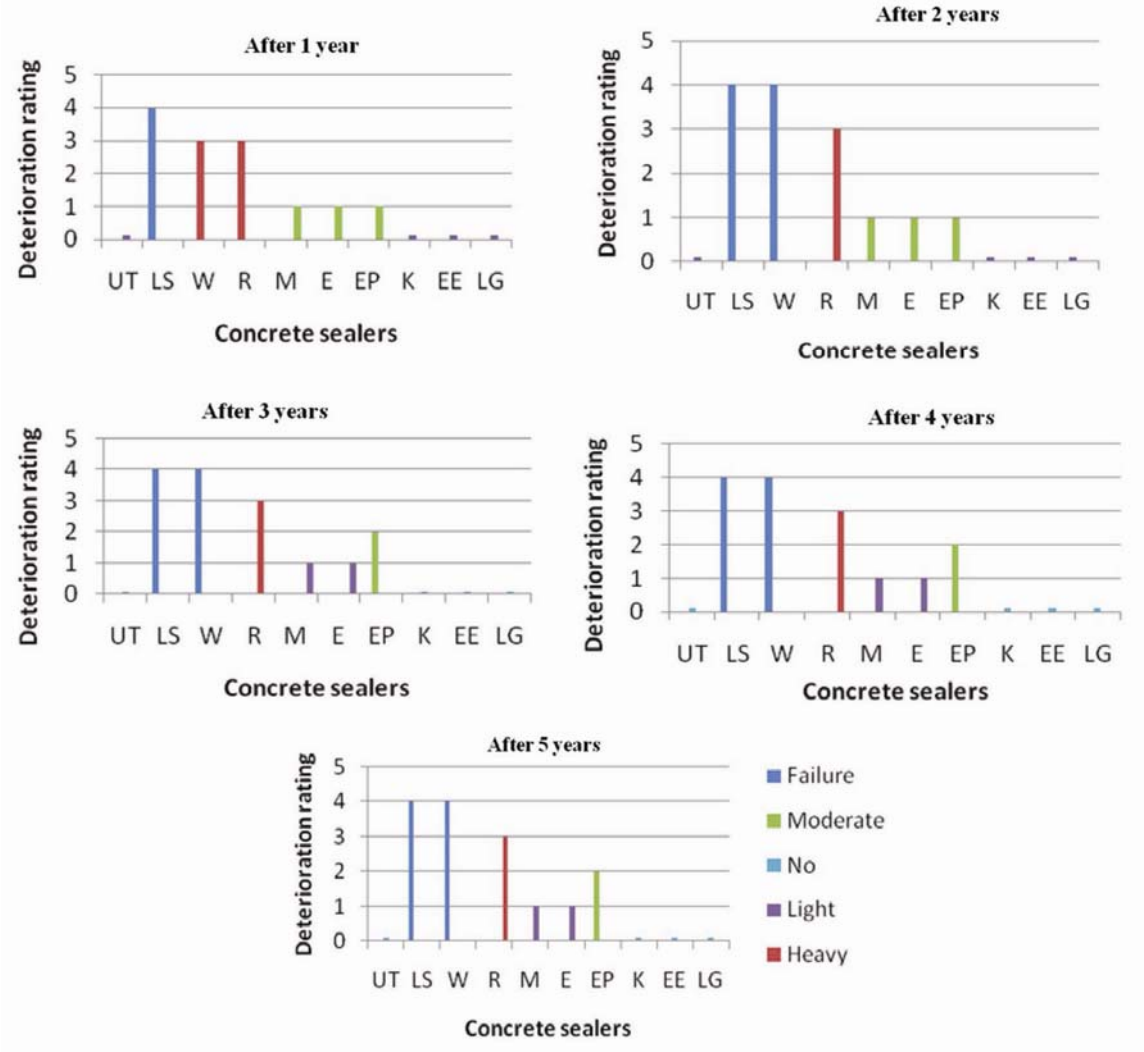

Figure 6. Deterioration rating on concrete beams from 1 to 5 years.

The durability of La Shield WR Xtra was recorded 2 years for protection. The concrete core treated with Magik impregnator exhibited water absorption of 1.18%, 1.18%, 1.41%, 1.51% and 1.71% after initial, 1, 2, 3 and 4 years respectively. The water absorption drastically increased to 1.41% after 1 year. The durability of Magik impregnator was recorded 1 year for protection. The concrete core treated with RIK-SEAL Medium Gloss exhibited water absorption of 1.13%, 1.15%, 1.52%, 1.52% and 1.72% after initial, 1, 2, 3 and 4 years respectively. The water absorption drastically increased to 1.52% after 2 years. The durability of RIK-SEAL Medium Gloss was recorded 1 year for protection. The concrete core treated with Liquid Sealer LS-S exhibited water absorption of 0.93%, 0.98%, 1.03%, 1.11% and 1.20% after initial, 1, 2, 3 and 4 years respectively. The durability of Liquid Sealer LS-S was recorded for 4 years.

The successful application of appropriate concrete sealers into reinforced concrete surface protects is against ingress of water, soluble salts and other contaminants, and also extend its service life. It provides protection from destructive freeze/thaw cycles in exterior environment, as well as for embedded reinforcing steel. The results of experimental studies on white cement panels, concrete beams, cores and exterior surface of the Secretariat Building in Chandigarh are as follows.

The white cement panels coated with M, W, K, E, EE and EP, LG and UT did not turn yellow as they were rated one on comparison with gardner colour grading after UV degradation and yellowing resistance test. The concrete beams and surface area of the Secretariat Building treated with K, EE and LG did not show any deterioration in appearance, as they were rated zero on comparison with visual rating scale for surface deterioration. On the basis of the test for determining water absorption, K, LS and LG showed water-repellent activity up to 4, 4 and 2 years respectively. The colour of concrete beams under laboratory and field trials on the surface of the Secretariat Building treated with LS turned dark. They also turned cream in colour after UV

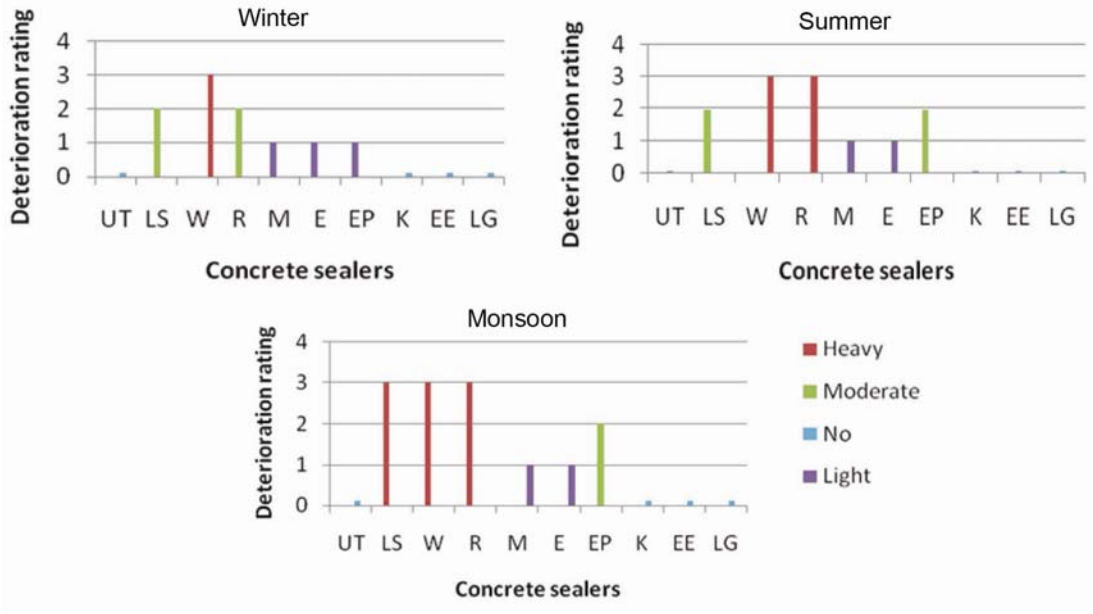

Figure 7. Deterioration rating on exterior surface of the Secretariat Building, during different seasons (after 7, 26 and 38 weeks).

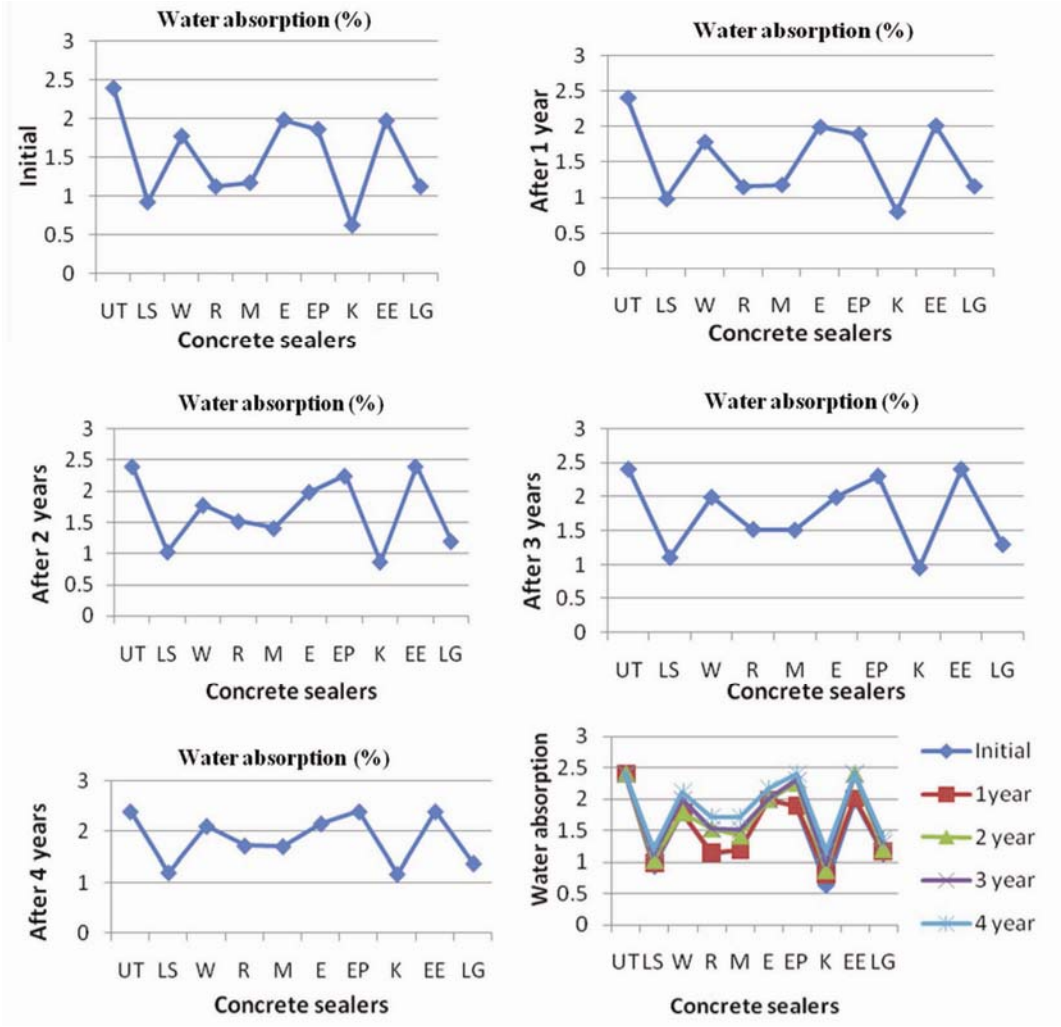

Figure 8. Effect of accelerated ageing on mean water absorption from initial to 4 years.

degradation non-yellowing test. EE initially showed more than 50% water absorption. Hence, LS and EE were not used for application on the exterior surface of the Secretariat Building. K and LG concrete sealers were found suitable for application on exterior surface of the Secretariat Building for restoration, as they exhibited water-repellent activity (durability), non-yellowing, UV resistance and were effective up to 4 and 2 years respectively. The results provide a convenient way to enhance the durability of exterior surface of the Secretariat Building from environmental deterioration. More investigations are required to explore other properties of the protective materials used in this study.

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ACKNOWLEDGEMENTS. We thank the Director, CSIR-Central Building Research Institute (CBRI), Roorkee for permission to publish this paper and Dr Ajay Chourasia (CSIR-CBRI, Roorkee) for continued support and useful discussions during the present study.

Received 10 December 2015; revised accepted 22 May 2016

doi: 10.18520/cs/v111/i7/1234-1241