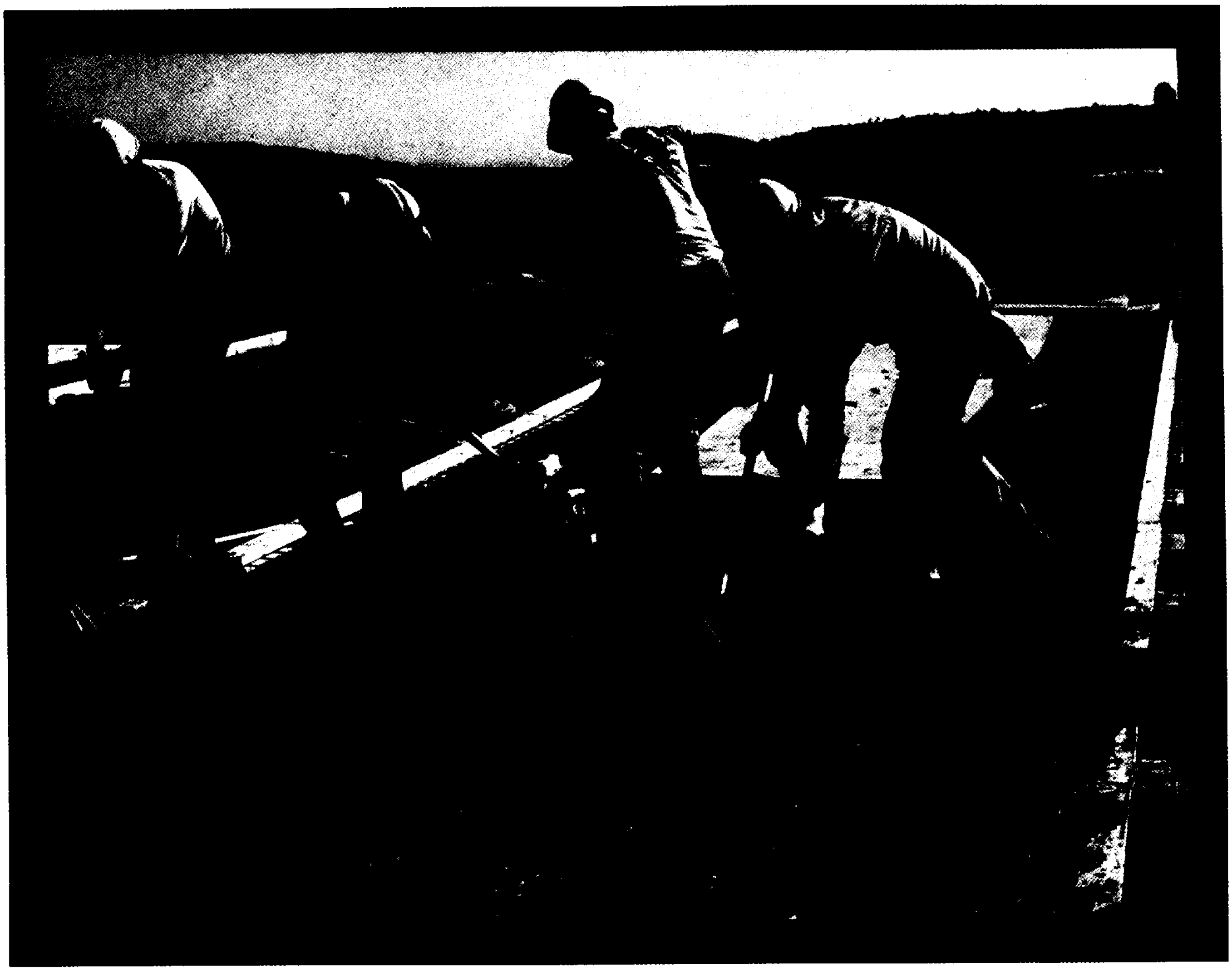
REPAIR & REHABILITATION II



Compilation 20

American Concrete Institute

Repair & Rehabilitation II

ACI Compilation 20

Contents

Preface

ACI Compilations combine material previously published in Institute periodicals to provide compact and ready reference on specific topics. The material in a compilation does not necessarily represent the opinion of an ACI technical committee —— only the opinions of the individual authors. However, the information presented here is considered to be a valuable resource for readers interested in the subject.

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Parking Slab Replacement Uses Innovative Geonet Drainage System

Rooftop Plaza Rehabilitation

by Robert Tracy

Concrete slabs are generally very durable, but some environments and conditions of use can lead to accelerated deterioration that sometimes leads to expensive repairs. In one such instance, geosynthetics were used during reconstruction of a relatively new rooftop parking slab on a large office building near Denver, Colorado, that failed prematurely.

Design and construction

The original roofing system consisted of a conventionally reinforced structural slab, a rubberized asphaltic membrane, and a rigid insulation layer sandwiched between two thin protection boards and an unbonded concrete topping slab. This slab served as a wearing surface only and was not part of the structural building system. The primary functions of the various components are:

- The structural slab carries all system live and dead loads.
- The membrane layer prevents leakage into the building.
- The lower protection layer prevents damage to the membrane from additional construction and isolates the insulation/membrane.
- The insulation layer reduces building heat loss.
- The upper protection layer isolates the insulation from the concrete wearing slab above.
- The unbonded topping is a wearing surface for auto parking.

The concrete topping slab, situated directly over occupied office space, accommodates 750 to 800 vehicles. Maintenance operations considered typical involved joint sealing, minor concrete surface repair, and periodic sweeping and cleaning. Similar systems have been known to provide from 20 to 30 years of low-maintenance service life depending on use, exposure, and certain design features.

The original slab was constructed during the mid-1970s and began showing significant problems within the first three years of service. Early problems developed near drain inlets and consisted of disintegrated concrete encasements (diamonds) around drain basins. By 1979, concern had developed over the integrity of isolated slab areas beyond the drain diamonds and the owner commissioned a study to determine the specific nature and extent of the problems.

The evaluation

The study of the parking slab included visual observations, materials evaluation, nondestructive testing, and a review of original construction documents and field reports. Results indicated that the principal deterioration mechanism was the saturation of concrete surfacing caused by poor drainage along the interface between concrete topping and insulation. This led to damage by frost action that was so severe that many of the joint seals were rendered useless by the third and fourth winters.

Joint sealant failure caused rapid saturation of many slab areas as water entered the slab-joint system, became entrapped atop the protection layer, and rapidly saturated joint faces, causing progressive damage to adjacent surface areas.

Without subsurface drainage, moisture that penetrated through the joint system could only escape by percolation along the interface between the concrete and the pro-

(left) Original condition of parking slab.
(above) Suitability of the filter/separation layer in the drainage net system was evaluated in a trial installation.

tection layer. This saturated the concrete topping along all joint surfaces for extended periods of time. Scaling from frost damage is most severe on saturated concrete.

The deterioration was progressive and would eventually render the slab unserviceable. An appropriate remedial action plan was needed.

Analyzing the alternatives

Predicting the useful service life and judging the cost effectiveness of various repair schemes proved difficult and inconclusive. Reaching a decision to spend considerable money for repairs with only limited data on useful service life was a major stumbling block to proper consideration of partial repairs. To keep the slab in service, Band-Aid repairs were performed, first during slab investigation and periodically thereafter.

After lengthy deliberation (and several additional years of further deterioration), an updated study helped persuade the building owners that the only practical and predictable solution was to remove and replace the entire wearing surface. This replacement occurred when the existing slab system was eight years old. By then, large portions of the roof parking lot were closed to traffic because of total slab disintegration.

Recommendation

Design criteria were established for the replacement system based on the data and evaluation from the previous investigation and from further research. Some of the possibilities included:

- Restoration in kind using high-quality concrete.
- Providing insulation board with subsurface drainage features.
- An underdrain system to eliminate subsurface water entrapment.
- Combinations of these systems or concepts.

After lengthy debate, a decision was reached to use a new underdrain system and high-quality concrete for rooftop restoration. Selecting an appropriate underdrain system involved a review of three options: loose drainage gravel, a stabilized drainage aggregate section, or a geotextile separation/filter layer and drainage grid.

Evaluating the underdrain alternatives was more qualitative than quantitative. A number of factors were identified that were considered important for proper system performance. These factors are described in Table 1.

System characteristics were rated one through four, respectively, with a rating of one being very undesirable and four being very desirable. Table 2 shows the values given each characteristic for the alternative systems. The totals indicate the geocomposite system is the most suitable.

After reviewing the available data, including cost factors, the geocomposite drainage system was selected. The system was tested for flow capacities, load characteristics, and unrestrained or low topping/net slip potential. A polyethylene geonet was chosen for the underdrain with a polypropylene woven sheet for a slip sheet and separation layer immediately beneath the concrete (Fig. 1).

Transmissivities were checked at various confining pressures (vertical load) and it was determined that a suitable flow capacity was provided

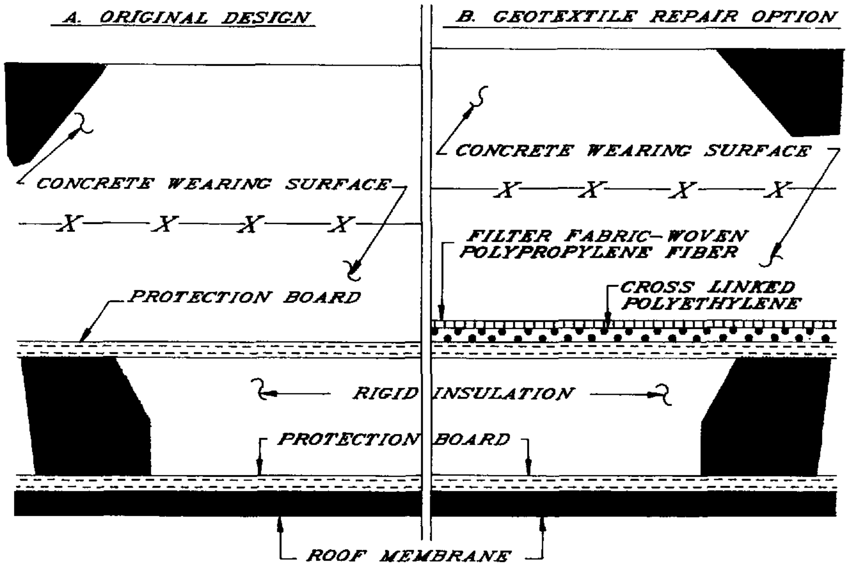


Fig. 1—Schematics comparing original design with geotextile repair option.

at all operational load levels. Tests were also run to determine insulation load-deformation characteristics in conjunction with the drainage net system. The first helped define grid lockup potential at the net-insulation interface. Extruded polystyrene board was the rigid system used for roof insulation.

Trial installation

A trial system installation was completed on the actual rooftop to evaluate the suitability of the filter/separation layer between the drainage net and the concrete topping slab. Two filter-fabric materials were tested, and concrete mixes were also varied to determine the effect of different water-cement ratios on cement paste permeation through the filter layer and possible bonding of the filter layer to the topping slab.

The trial indicated that both fabrics were equally effective at reducing paste permeation into the cross-linked polyethylene geonet, but the polypropylene fabric developed minimal bond to the concrete topping, whereas the woven fabric — spun bonded-polyester — adhered tightly and became impregnated with and even embedded into the lower concrete slab. Consequently, the woven material was specified for the slip sheet/filter fabric material.

System installation

Concrete removal began in early July and proceeded at a rapid pace. Because considerable saturation of the underlying insulation layer was revealed, the insulation was removed and replaced as well. Saturation was so severe at building low points that it was necessary to install a second drainage layer beneath the insulation in roof valleys and along drainlines.

Damage to concrete parapet walls at the base of the slab was also found at isolated locations and a special closure detail was worked out to tie the new topping slab system to the existing parapet wall without unnecessarily damaging or disturbing the wall, which carried the building facade. Salvaging the existing wall realized considerable cost and time savings, while maintaining the building's outward appearance.

Once the insulation was removed, the membrane was inspected for damage, and spot repairs (on less than 10 percent of the surface) were performed. Exposure of the membrane to the elements during reconstruction was mini-

Table 1 — Design criteria

Criteria	Description	Value
Load capacity	System must sustain loads without deformation	1000 psf
Reliable drainage	System must free drain under anticipated working loads	2 to 4 gal. per lineal foot of width
Weight	System must apply minimum dead load to existing rooftop	<1 lb/ft²
Low profile	Add maximum change to roof grades and evaluation	¼ in.
Durability	No significant changes to effective load or flow capacity with time	Corrosion resistant & temperature stable
Restraint	Low potential for lockup between topping & insulation	Low friction coefficient between filter fabrics & drainage net
Ease & speed of construction	Practical application	Manageable logistics; ease and simplicity of installation

Table 2 — Weighted performance features

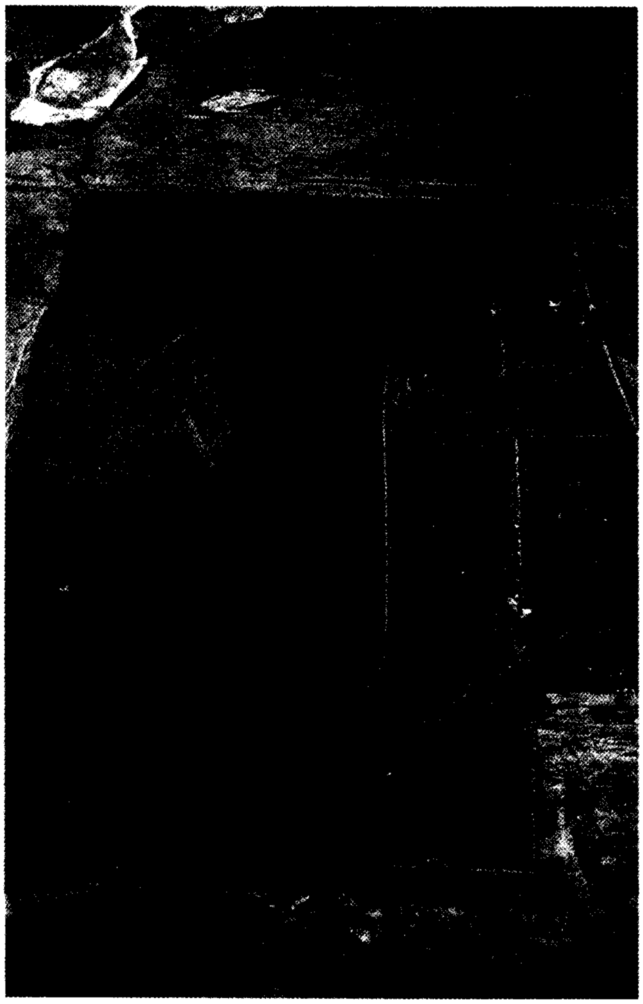
	Loose gravel	Stabilized gravel	Geonet
Reliable drainage	3	3	3
Suitable weight	1	2	4
Load capacity	4	4	3
Profile	1	2	4
Durability	4	3	3
Restraint	3	2	4
Construction time	2	1	4
Total	18	17	25

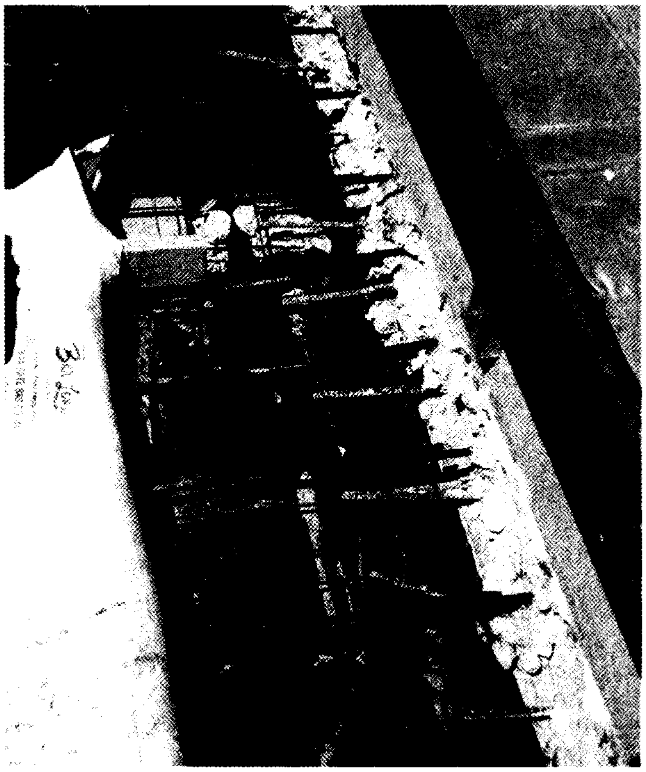
(top left and right) Concrete removal revealed significant damage to the underlying insulation layer.

(bottom left) Spot repairs were made to less than 10 percent of the membrane surface.

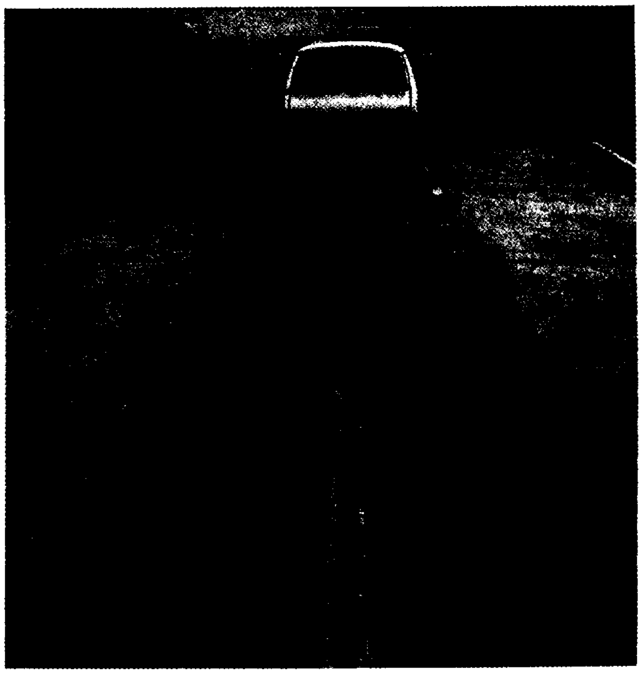
(middle right) The insulation and protection layers and geonet underdrain were placed.

(bottom right) Damage to concrete parapet walls required a special closure detail to tie the new topping slab system to the wall.





Concrete was place using a strip method to provide proper control joints in the concrete topping.



The finished slab. The system is performing satisfactorily with no reports of operations or maintenance problems.

mized to avoid damage to the building below.

With membrane repairs complete, the insulation and protection layers and geonet underdrain were placed. Formwork was then installed for concrete replacement using a strip method to provide proper control joints in the concrete topping. Strip edges became construction and/or isolation joints depending on the section encountered.

Concrete placement began three to four weeks into the project and a sequenced operation was established to keep removal and replacement on a cycled basis. Special control was used throughout the topping replacement to provide both large-scale movement and crack-control capability.

The building was in continual use during construction and all operations were performed to cause a minimum amount of disruption. Concrete removal, which generated noise and vibration, were performed in the evening hours, and concrete replacement and formwork was done during the day. Weekly progress meetings were held to coordinate operations and resolve any problems that developed. By mid-October, concreting was nearly complete and final cleanup was underway.

Performance

System performance was closely monitored during the first year and, with the exception of some isolated joint-matching problems, sealant problems, and miscellaneous concrete cracking, the system is performing satisfactorily.

As a result of this operation, it can be concluded that geotextile drainage nets, when properly designed and constructed, can provide suitable underdrain layers for plaza decks. With proper design criteria, material selection, and preconstruction testing, these systems can provide a suitable approach for restoring unbonded topping slabs that have undergone premature damage.

This installation firmly establishes that geonet systems can play a significant role in plaza deck restoration, however, although the anticipated performance in the above project has been achieved, it should not be concluded that this system can be used for all applications without further research. Recommendations for further research include:

- Determining slip coefficients for various combinations of geosynthetics over geonet underdrains.
- Long-term deformation characteristics associated with load and temperature.
- Abrasion resistence of geosynthetics systems.
- Shearing resistence to braking vehicle loads.
- Long-term shrinkage and creep aspects of geocomposites.

This installation is considered innovative. Until further design information is developed and research has been performed, the use of this system should only be considered on a project following study and appropriate selection of geosynthetic fabrics. Successes achieved, however, warrant consideration of this system as one viable and cost effective approach to plaza deck restoration.

ACI member **Robert G. Tracy** is principal and founder of Tracy Materials Consultants, Ann Arbor, Michigan. He established this firm to broaden his activities and involvement in restoration engineering. Tracy received both his Bachelor's and Master's degrees in civil engineering from Michigan Technological University. He is a member of ACI Committees 362, Parking Structures; 364, Rehabilitation; and 546, Repair of Concrete.

Repair process developed by Japanese cement company utilizes polymer cement mortar and organic paint film

Repair Method for Salt-Damaged Reinforced Concrete Structures

Salt damage has been an issue in Japan since around 1981. From 1982 to 1984, government organizations and cooperating associations conducted country-wide surveys of salt damage, focusing on railway bridges, road bridges, building structures, and harbor facilities.

A variety of methods are used to inhibit corrosion of reinforcing steel in concrete. When large quantities of external salt are expected to be present, corrosion protection is usually achieved by either preventing penetration of corrosives into the concrete, preventing contact between corrosives and reinforcing steel, or controlling the electric potential of the system. Coating the concrete surface is currently attracting attention as a salt damage repair method.

The Asano Refresh process uses prepacked aggregate when a large part of the crossection must be replaced, as in this salt-damaged offshore pier girder.

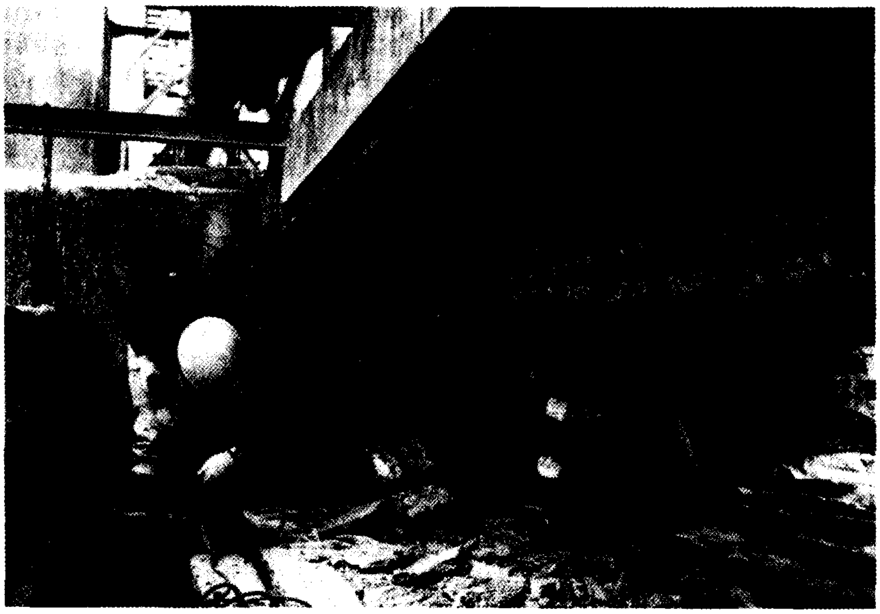
Asano Refresh (AR) process

The Asano Refresh (AR) process, developed by Nihon Cement Co., Ltd., is a salt damage prevention method that incorporates a concrete surface coating (Fig. 1).

The AR process is a concrete body modification process that improves the durability of existing concrete structures by protecting the concrete against further invasion by harmful substances that can degrade the structure. It can also be applied to a new concrete structures to prevent future degradation.

The combination of materials used in the AR process (Table 1) results in repairs having the following characteristics:

- High adhesivity.
- Protection against the permeation and diffusion of carbon dioxide, oxygen, and water, and against neutralization.



Any remaining deteriorated concrete is chipped away prior to beginning the repair.

Table 1 — Main effects of the materials used in the Asano Refresh process

Material	Effect
Corrosion inhibitor (undercoat)	Specially prepared urethane resin (the main component) reacts with rust to inhibit the rust growth. Consequently the surface preparation is only required to a level of 3.
Corrosion inhibitor (finish coat)	
Base strengthening agent	The base strengthening agent offers both the durability of inorganic type and the impregnating ability of organic type. It improves the strength of bare surface weakened by frost damage.
Cross sectional repairing material	The cross sectional repairing material has small drying shrinkage and excellent adhesivity to the base material. No primer is necessary on the base. (Use with SBR latex)
Non-flat preparation material	The non-flat preparation material has small drying shrinkage and excellent adhesivity to the base material. It can also be used to repair a relatively shallow cross sectional chipped part without primer. (Use with SBR Latex)
Surface coating material	The surface coating material has excellent gas permeation resistance, water resistance, crack resistance, and chloride ion permeation resistance. It prevents the invasion of external oxygen, water, chloride, and carbon dioxide. (Use with SBR latex)
Finisher for salt damage prevention (sealer)	The finisher for salt damage prevention is an elastic material to enhance the salt damage prevention of the surface coating material. It has an excellent crack pursuability.
Finisher for salt damage prevention (finish coat)	
Prepacked aggregate injection material	The prepacked aggregate injection material is non-shrink and shows an excellent adhesivity to the base material. It is most suitable for large cross sectional repair at an inverse position. (Use with SBR latex)
Mixed solution	The mixed solution is a styrene-butadiene rubber (SBR) specially formulated for the AR process. By combining with various premix materials, it provides the necessary characteristics.
Injection material	The material is a polymer cement injection material mainly composed of very fine cement particles. It can be injected into fine cracks. (Use with SBR latex)

- Protection against the invasion of chloride ions and salt damage.
- Easy rust removal and rust preventive work on reinforcing steel; high quality rust proofing.
- Stable performance of inorganic materials and specially formulated styrene-butadiene rubber (SBR) latex, which are mixed under strict quality control.
- Economical compared with resin repair processes.

Repair process using prepacked aggregate

Prepacked aggregate grouted with SBR polymer cement mortar is used when a large part of the concrete crossection must be replaced. The accompanying photographs illustrate the steps used to repair a salt-damaged offshore pier girder using this technique.

Remaining deteriorated concrete was chipped away, and sandblasting was used to clean the concrete surface and remove rust from the reinforcing steel. Corrosion inhibitor (primarily a urethane resin) was applied to the reinforcing steel, and enough formwork installed to support the prepacked aggregate. The rest of the formwork was then installed and the grout injected.

After removal of the formwork the surface coat (SBR polymer cement mortar) and finisher acrylic elastic finish material) were applied. The surface coat incorporated a layer of alkali-resistant glass fiber mesh across the joint line between the original concrete and the repair.

Salt damage prevention system

The surface of reinforcing steel in high alkalinity concrete is covered with a passive film that protects the steel againsts corrosion. However, when chloride ions penetrate the concrete they can destroy the passive film and corrode the steel. The salt damage prevention system of the AR process uses the surface coating and finish materials shown in Fig. 1 to protect the concrete by preventing the invasion of oxygen, water, and chloride.

Following is a discussion of the effects of the materials used in the salt damage prevention system (polymers, polymer cement mortars, combined organic paint film) and the effect of the system as a whole.

Table 2 — Water vapor permeability, chloride ion transmission rate, and chloride ion penetration depth of the salt damage prevention system in the AR process

		Sample			Water vapor permeability (mg/cm²·day)	Chloride ion transmission rate (μg/cm²·day)	Chloride ion penetration (mm)	
		Surface coat (mm)	Sealer coat (g/m²)	Finish coat (g/m²)			after 1 month	after 3 month
Salt damage prevention system in the AR process	I	2	100	800	0.87(<1)*	0.35(<1)	0	0
	II	1	100	800	0.86(<2)	0.34(<1)	0	0
	III	1	100	400	1.00(<2)	0.36(<10)	0	0
Concrete body (uncoated)							6.1	10.1

*Objective values in parentheses.