The Development of ISR Technology

This booklet describes the process of how new technology was developed for cementitious materials used to repair concrete. The primary objective was to develop repair materials for concrete that are more durable than existing technology. Critical in formulating the new material was the emphasis of compatibility of the repair material to the parent concrete. Replacing a portion of the sand in the mix with fine recycled rubber aggregate improves the extensibility of the repair mortar. This results in the material's resistance to cracking caused by restrained shrinkage stresses. Conproco has termed this technology ISR for Internal Stress Relief.

ISR technology exhibits greater ability to withstand shrinkage-induced stresses before cracking. Another objective of the project was to maximize the use of recycled materials to create am more environmentally friendly repair mortar for concrete.

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The U S Navy sponsored a Small Business Innovative Research (SBIR) grant with the primary goal: "Development of a Crack-Resistant Durable Repair Material for Navy Structures." A secondary goal of the project was to maximize the use of recycled raw materials to produce a truly environmentally friendly cementitious concrete repair mortar. Conproco/MER Corporation were successful in securing the grant by proposing the use of fine rubber aggregate as an approach that had the potential to satisfy both of the Navy's requirements. The result of this effort was the development of a technology Conproco has titled "Internal Stress Relief". ISR achieves crack resistance in the repair material by reducing the stresses in cementitious mixes caused by restrained drying shrinkage strains. ISR technology enhances the stress relaxation potential due to creep by replacing part of the sand with fine rubber aggregate.

The Navy maintains more than 100 facilities world-wide with most located in warm climates. Warm salt water is a harsh environment for concrete, particularly in piers which cycle through soaking and drying due to tidal change. The Navy was not satisfied with the relatively short life of the repairs made to its concrete structures and was seeking a new approach to improve long-term durability. Developing a material to meet the Navy's requirements was a significant challenge. Conproco was fortunate to have the assistance of a number of organizations and individuals in developing this technology including:

Dr. Benoit Bissonnette, Universite Laval
Alexander Vaysburd, Vaycon Consulting
Wayne Salisbury, Conproco Corp.
MER Corporation

The complete findings of the report submitted to the Navy are available from Conproco upon request.

The three-year long process to develop a new material technology began with learning first-hand how the addition of rubber aggregate effects the characteristics of cementitious materials. The next challenge was to develop a repair mortar using elevated levels of recycled material. A number of mix designs where developed for comparative testing. Once the final mix design meeting the performance criteria was chosen, field experiments were conducted. Field installation was conducted at Port Hueneme California. Structural Preservation Systems was contracted to mix and install the material. After completion of the field experimental repair program and monitoring for cracking behavior of the repairs for 120 days, a comprehensive material testing program was implemented in accordance with ACI 364.3R "Guide for Cementitious Repair Material Data Sheet". Laboratory testing was conducted at Université Laval, Quebec City, Quebec, CTL Group, Chicago, and Conproco's laboratory.

As shown in **Figure 1** there are 5 critical material factors effecting concrete durability. The repair material must be compatible with the material being repaired. Compatibility in concrete repair is defined as "the balance of physical, chemical and electrochemical properties and deformations between repair and existing substrate that ensure the repair withstands all anticipated stresses induced by loads, volume changes, chemical and electrochemical effects without distress and deterioration over a designated period of time.*

Tensile stress concentration at the top and bottom of the rubber particle included in the cementitious matrix results in multiple tensile micro-cracks that form along the rubber particles. These micro-cracks propagate in the cement matrix until they encounter another rubber particle. Due to the ability of the rubber to withstand large tensile deformations, the particles act as springs, preventing further micro cracking which ultimately can lead to a macro-cracking and failure.

*Emmons, P, H. and Vaysburd, A.M, Factors Affecting Durability of Concrete Repair & Compatibility Considerations for Durable Concrete Repair

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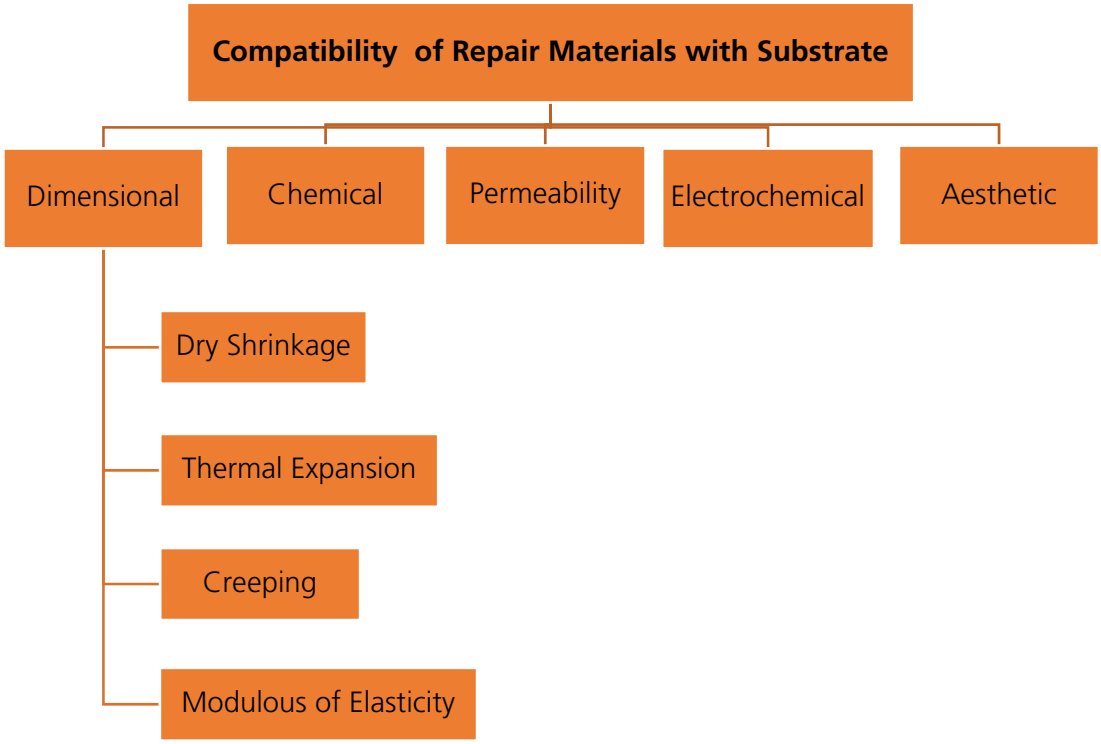

Figure 1: Factors affecting compatibility in concrete repair system

Typical elastic moduli of various materials

Material	Elastic modulus (psi)
Rubber	1,000
Human cartilage	2,500
Unreinforced plastic	200,000
Plywood	1,000,000
Concrete	3,600,000
Ordinary glasses	10,000,000
Aggregate (normal weight)	15,000,000
Iron and steel	30,000,000

Figure 2: Typical elastic moduli of various materials

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The rubber aggregate lowers the elastic modulus of the repair material while maintaining the performance characteristics required for a durable repair.

The first commercial application of **ISR AG** was a parking garage in Albany, NY. The contractor had repaired the same garage deck area on two separate occasions with different repair materials. Both materials failed within 28 days of installation. The repairs using ISR AG did not fail. There has been no cracking evident since the installation in Fall 2015. The applicator did not observe any difference in mixing, placing and finishing ISR AG as compared to other repair materials.

ISR V/O was installed in the 1818 Market St building in downtown Philadelphia during the Fall/Winter of 2016. The repairs to the massive concrete structure were made using typical application techniques. The applicators observed that the material mixed and applied as expected of a vertical and overhead repair mortar. No cracking or delamination of repairs has been observed.

ISR technology has proven successful in the critical areas of compatibility with one exception – Aesthetics. To address this Conproco has introduced **ISR CM** (Color Match) a repair mortar specifically formulated to match the color of existing concrete surfaces. By addressing the aesthetic compatibility with the repair mortar the need to hide the repairs with a coating is eliminated.

ISR products are compatible with each other which allows deep patching with either ISR AG or ISR V/O (lower cost than CM) and finishing the last 1" of the repair with ISR CM.

Field experience confirms laboratory test results demonstrating this technology offers superior performance in its compatibility with existing concrete as well as long-term durability.

- ISR AG packaged in 60 lbs. bags with 3/8" aggregate, for deep repairs, particularly decks and balconies
- ISR V/O packaged in 50 lbs. bags for vertical and overhead repairs
- ISR CM available in 50 lbs. pails with 23 standard concrete colors and custom matching. Also available in 50 lbs. bags with a 112 bag minimum order.