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Selection of Repair Materials Using Expert Advice

by Noel P. Mailvaganam and Tony Alexander

Repair and rehabilitation of concrete structures claims over 50% of the construction expenditure, and recent projections indicate that this trend will continue at least to the year 2000.[1] This substantial portion of construction expenditures addressing the specific requirements of repair and refurbishment of structures has influenced the market for repair materials, specialized techniques and services, and created an impetus for further research and development.

"In evaluating materials, one has a choice either to simulate use or to understand well enough to be able to predict performance. Simulation is helpful but not reliable. Understanding is more reliable." —Peter C. Hewlett

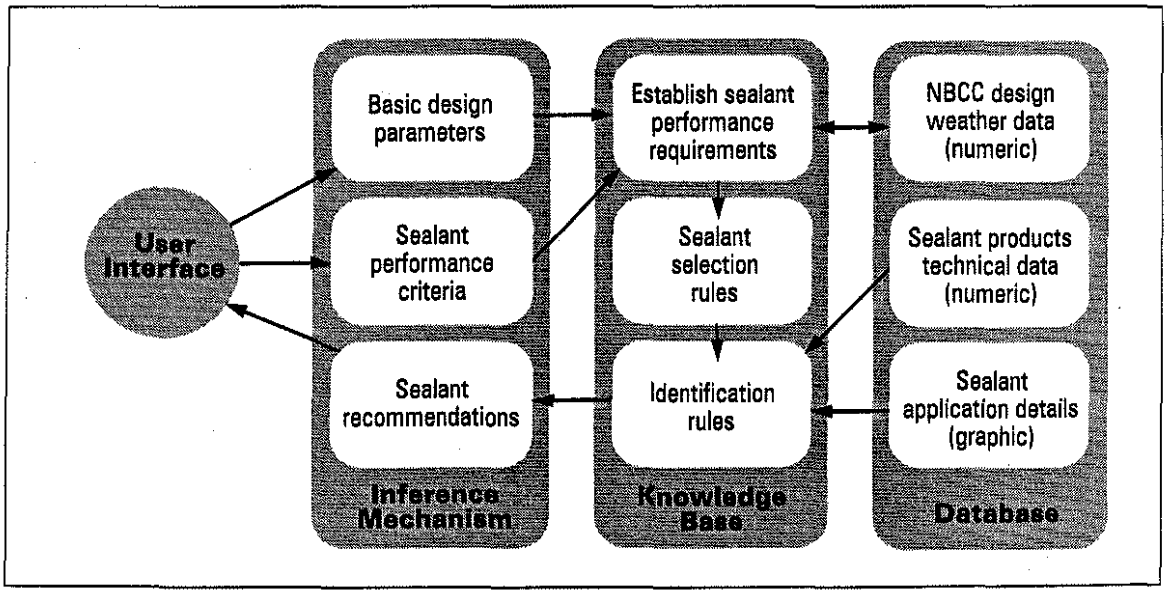
Many engineers, in making recommendations to their clients, have a concern not to expose a client to products and procedures that do not have an established record of performance. They tend, therefore, to be conservative and to recommend materials with which they are familiar through long association. The significant differences that exist between repair and new construction dictate the use of the most effective combination of available materials and procedures that address the specific requirements of a repair. This makes it incumbent on engineers to continually update their knowledge of new product performance.

The availability of a multitude of proprietary repair products has increased the complexity of material selection and heightened the potential for problems to occur. Evaluation by testing and research has not kept pace with the development of new products. Thus, products are being used before the design professional can be assured that they do indeed fulfil the desired requirements.

Today's designers and engineers must make material and technique selection from an ever-increasing variety of new products and services. Material properties must be systematically analyzed to arrive at the most appropriate use and application in repair and refurbishment. The prospective user of these materials and services, therefore, requires the aid of a rational, analytical method to evaluate and select materials from the myriad of products available.

Fortunately, it is normally not necessary to be familiar with the whole range of products. As the number of material and service options has grown, so has the information network that facilitates identification of the best material for a particular application. With access to expert advice, published information and data bases, choosing the right material and technique need not be a daunting task.

Much of the work can be done by the designer and engineer or end-user, at least in the initial stages. The first and most important step is to determine the factors contributing to the deterioration, the rate of deterioration and its extent so that an assessment of the structural significance of the damage can be made. Information generated from this step will determine whether the materials used should reinstate structural integrity, provide cosmetic characteristics or protection from the environment, or all of these.



The focus in Knowledge Based Expert Systems (KBES) is on knowledge rather than data, as is found in conventional software programs.

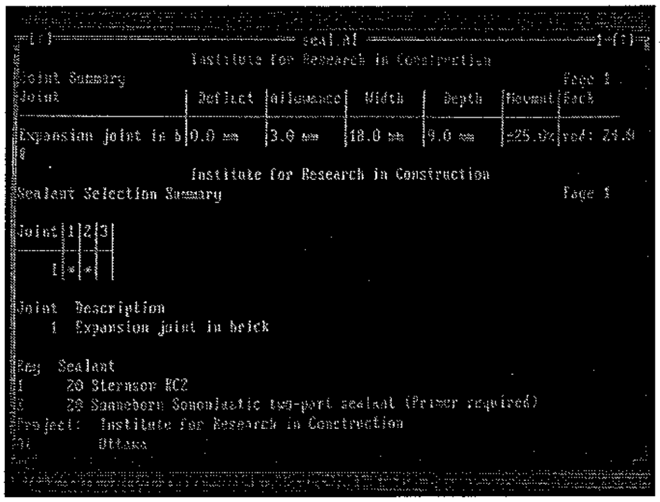
Selection of the repair procedure and materials should reflect the important functional requirements of the above objectives. Whenever possible, properties should be quantified in standard engineering terms, so that the search can be systematic. These should then be rated on a scale of priority. Time and thought invested at this stage will avoid omissions and problems later in the process.

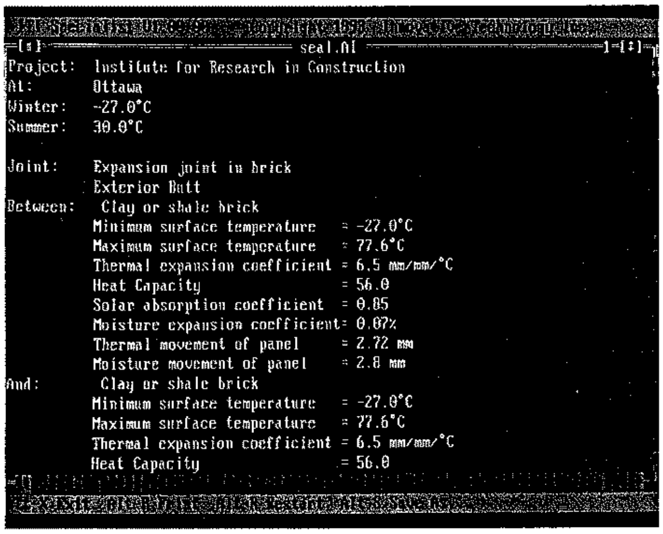
Determining material requirements and installation specifications

It is important to identify the cause of the damage before selecting a material for a particular repair. Whether the cause is corroding rebar, poor freeze-thaw resistance, high impact, abrasion, chemical attack or any one of numerous other reasons, correcting the cause of deterioration is the primary requirement in a durable repair. In addition to the deterioration of concrete, the breakdown of other auxiliary materials (such as sealants, coatings, membranes, etc.) which form the complex assembly of a structure should also be considered. For example, polymeric products often interact with other materials with which they are in contact to form compounds which lack the characteristics of the original materials. The breakdown of such materials could mean not only the loss of the critical functions they perform, but may well lead to degradation of structural members.[2]

Material selection, therefore, should be based on the compatibility of the selected material with the concrete substrate and other materials with which it will be in contact in its service environment, while taking into account the intended use and the method of application.

Many of the mechanical properties to be considered are obvious. Tensile, impact and compressive strength, stiffness, dimensional stability, percent elongation, chemical resistance and resistance to freeze-thaw cycles are typical. However, many demands for the repair of a structure are subtle and often missed in the initial selection because they are secondary requirements that either stem from the interaction of the element with other parts of the structure or the response of the structure as a whole to environmental conditions. In the example of a structural repair, a specifier may believe that a high-strength material with excellent durability properties would provide the best insurance against future failure. However, if these desirable properties were accompanied by a modulus of elasticity significantly higher than that of the member being repaired, the load may not be





***Above:** Expert system identifies materials meeting performance requirements.*

***Left:** Material and environmental factors determine range of expected movement.*

properly distributed resulting in a concentration of stress in the repair material. Failure in the repair material may soon follow—despite the superior strength.

Additional requirements for long-term durability and compliance with codes and standards force consideration of other properties as well. These may include fatigue, creep, heat deflection, thermal conductivity, thermal and moisture related expansion, flammability, UV resistance, electrical properties, water absorption, regular cycling of environmental factors and assembly requirements.

Although a few major product properties may figure in the choice of a material, many more must be considered before they can be discounted. Some properties are mutually exclusive—for example high wear resistance and good crack bridging characteristics for elastomeric parking garage membranes—and to specify them together is to seek a non-existent material. Practical aspects also enter the equation; they include the product's sensitivity to changes in ambient weather conditions during installation, ventilation of the work area, turn-around time, material cost, availability, finishing and maintenance costs.

The design engineer, in considering a product for a specific application, must also evaluate critically the product's field history under conditions similar to the job at hand, the relevance of the test data in the product literature, and any limitations imposed by weather conditions or potential for concrete carbonation from vehicle exhaust fumes existing at the time the work is carried out. Job specifications which take into account these factors should then be developed to define the material or product type required and the quality of the installed system.

Material selection

Once the material and job specifications have been outlined, the search for a suitable material begins. Almost every repair job has unique conditions and special requirements and when these criteria are known it will often be found that more than one material can be used with equally good results.

The nature of the search and selection effort is determined by several factors: the complexity of the repair, how much the designer knows about engineering materials used in the repair, job specifications, time available for the search, and the degree of confidentiality desired. It can be limited to a one-person effort, relying on information published in manuals and catalogues, or it might be a sophisticated team approach involving the design engineer, contractor, owner, material supplier and perhaps consultants as well.

One person effort. Probably the most common approach is one in which the repair work is designed, specified and supervised by a single person who determines the suitable product through a combination of past experience and updated information obtained from the product manufacturer.

Product manufacturers know their products and how they are applied, and can therefore help determine the appropriate products and application methods necessary. Some suppliers and construction research organizations have developed proprietary product charts and computer-aided techniques to help material selection. Typically 8 to 10 material criteria are specified in a computer-aided search. Usually, after three cycles of dialog with the data base, a suitable short list of product candidates is obtained.

Team approach. Depending on the type of project, the product supplier may work one-to-one with the design engineer, or be an integral part of a team to establish material and job specifications. Due to the increasing understanding of the complex requirements of the repair process and the increase in technical sophistication of design engineers and end users, the team approach is becoming more frequent and important.

The team approach is partly due to the initiative taken by product manufacturers who are competing more fiercely for available materials and are increasingly willing to become involved in material and job specification development at an early stage of a project. The high level of information now offered to engineers by product manufacturers, consultants, and research and public agencies, allows the ready development of specifications that are pertinent to the job at hand.

Aid from associations. Industry associations have long been prominent in aiding in material selection. Organizations such as the American Concrete Institute (ACI), Army Corps of Engineers, Transportion Research Board and the International Concrete Repair Institute (ICRI), play an important advisory role. Both the ACI and the Corps of Engineers (which conducted an exhaustive study of proprietary repair materials and procedures under the REMR program) have a wealth of published and computerized data bases at their disposal and can draw on the expertise of product manufacturers, consultants, contractors and researchers.

Expert advice. Private consultants offer expertise for design and material selection. Experts are knowledgeable in their specialty, are familiar with the complex issues to be addressed, and are capable of seeking new solutions to specific problems. The expert usually addresses a client's specific concerns personally and develops unique and practical solutions.

Many now employ customized computer-aided techniques (expert systems) that help match causes of deterioration with materials that are suitable for the particular environment and service conditions and compatible with the intended substrates. Typically, the knowledge-base component of an expert system contains what is known about the subject area, including an expert's day-to-day problem-solving ability, knowledge from published standards, guidelines of accepted practice, and an explanatory text.

Concluding remarks

It is the responsibility of the design engineer to ensure that the selected repair material has the requisite properties that will enable it to function for the design life of the repaired structure. For each application, one must decide carefully which properties are the most significant. However, the current scarcity of comprehensive data and suitable guidelines leaves some uncertainty as to how to proceed with the design and execution of durable repairs.

Expert advice which helps to rationalize the many chemical and physical variables and multiple material choices for the intended job is often beneficial to the design process. In many instances, such advice provides an organized approach to material selection, and can reduce the overall cost of the repair in terms of first cost, maintenance cost, or increased life expectancy, or some combination of these three.❐

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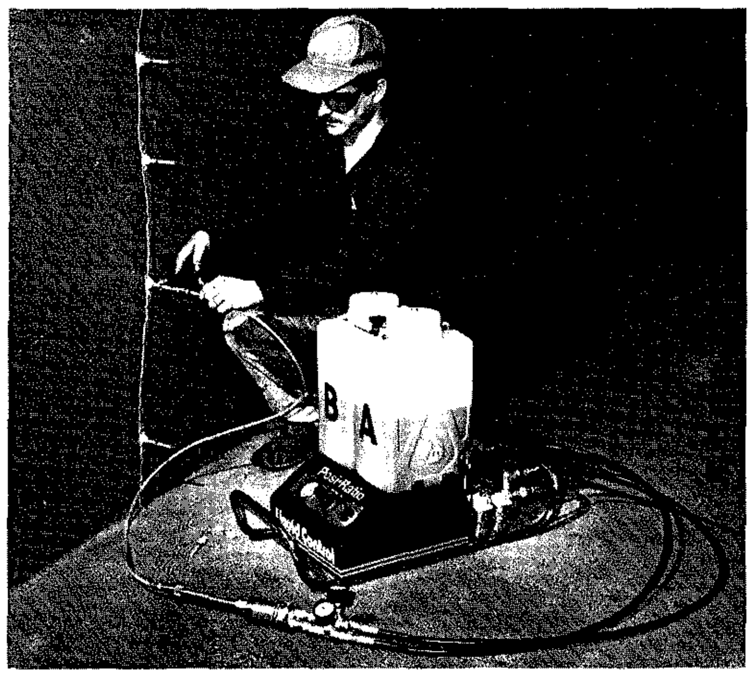

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