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Selection of repair materials using expert advice

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Repair and rehabilitation claims over 50% of the construction expenditure and recent projections indicate that this trend will continue at least till the year 2010. Such a substantial proportion of construction expenditure must be expected to influence positively the market for repair materials, specialised techniques and services. This indeed can be seen by the flood of new materials and expert services in the market to address the specific demands of the repair market. However, the phenomenal explosion of proprietary 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 fulfill the desired performances.

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

Fortunately, no one has 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 allows one to find the best material for a particular application. Through a combination of expert advice, published information and databases, choosing the right material and technique need not to be a daunting task.

Much of the work can be done by the designer and engineer/end-user at least in the initial stages. The first and most important step is to determine the cause and extent of deterioration of the treated element 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 aesthetical characteristics or protection from the environment or a combination of all these aspects. Selection of the appropriate method of repair and/or repair material should emphasise the important functional requirements of the above objectives. Whenever possible, properties should be quantified in standard engineering terms so that the search can be methodical as well as systematic. These properties 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.

This paper discusses the sequence of material selection from ascertaining the cause of deterioration to a comprehensive consideration of all factors that will impact on the compatibility of the selected material with the concrete substrate to the proper functioning of the repaired element in its service environment. It also identifies sources from which such information can be readily obtained.

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 other reasons, addressing and correcting the cause of deterioration is the primary requirement in a durable repair.

In addition to the cause of deterioration of concrete, the breakdown of other auxiliary materials (such as sealants, coatings, membranes, etc.) which form the complex system-assembly of a structure should also be considered. Polymeric products often interact with other materials with which they are in contact to form compounds that are devoid of the characteristics of the original materials. The breakdown of such materials could mean not only the loss of critical functions they perform, but may well lead to degradation of structural members. Selection therefore, should be based on the compatibility of the selected material with the concrete substrate, the intended use and the method of application.

Many of the mechanical properties to be considered are obvious. Tensile, impact and compressive strength, modulus of elasticity, stiffness, dimensional stability, percent elongation, chemical resistance and resistance to freeze/thaw cycles are typical. However, many demands for an appropriate 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. The additional requirements for long term durability and conformance to building codes and national standards may impose the inclusion of other properties. These may include fatigue, creep, heat deflection, thermal conductivity, thermal expansion, flammability, U.V. resistance, electrical properties, water absorption, subtle cycling of environmental factors and assembly requirements.

Although only ten or so 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 both of them 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 working area, curing turn around time, material cost, availability, finishing and maintenance costs. In addition, the designer and the specifier while in considering a repair product, must evaluate critically the following:

1. the product's field history under conditions similar to the job at hand
2. the relevance of the test data in the product's literature
3. limitations of the product.

Job specifications which take into account these items 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. 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 repairs, how much the designer knows about the engineering materials used in repairs, job specifications, time available for the search and the degree of confidentiality desired. It can be a simple one-person effort, relying on information published in manuals, catalogues or it can be a sophisticated team approach including the designer, contractor, owner, material supplier and perhaps consultants as well.

One-person effort

Probably the most common approach is to consult the product's manufacturer. They know their products and how they are applied and can therefore help determine the right products and application methods necessary. Some suppliers and construction research organisations have developed proprietary product charts, and computer-aided techniques to assist in material selection. Typically 8-10 material characteristics are specified in a computer-aided search and usually after three cycles of dialogue with the database, a suitable short list of product candidates is obtained.

Team approach

Depending on the type of project, the product's supplier may work one-to-one with the designer or be an integral part of a team to establish material and job

specifications. Due to growing realisation of the complex requirements of the repair process and the increase in technical sophistication of designers and end users, the team approach has become more desirable, frequent and important. The team approach is partly the initiative of the product manufacturers who are competing more fiercely for available markets and are willing to become involved in material and job specification development at the earliest stages. The high level of information now offered by product manufacturers, consultants, research and public agencies enables quick development of specifications that are pertinent to the job at hand.

Support from associations

Remedial procedures involve the use of both conventional materials, whose properties are well established and understood, and those recently developed. Therefore, information pertaining to the characteristics and criteria for the usage of newer materials is important and choosing the right product requires careful study.

Industry associations have long been prominent in aiding material selection. Organisations such as the American Concrete Institute (ACI) and the International Concrete Repair Institute play an important advisory role. The ACI has a wealth of published data and computerised database at its disposal and can draw on the expertise of product manufacturers, consultants, contractors and researchers.

Consultants

Private consultants offer expertise for design and material selection. Experts have usually several years of experience in their chosen fields and posses good analytical and problem solving skills. Two major characteristics that expert consultants possess are competency and ability to customise the specific needs of a project.

Many now employ customised computer-aided techniques (expert systems) that help match the causes of deterioration with materials that would be 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

The growing use of polymer based products in repair applications is both a boon and a cause for concern. Despite the wide ranging capabilities of these materials to provide solutions to concrete problems, many are unforgiving and not very user friendly. Engineers overlooking the differences in the response of concrete and polymers to changing temperatures and loading conditions, often specify polymers for the wrong applications. Contractors working with unfamiliar materials have found it difficult to adhere to the manufacturer's instructions for mixing and placing these materials.

Concrete is a relatively stiff 'elastic' material although its behaviour is slightly viscous over the long term. However, polymer materials are clearly viscoelastic and under certain environments are primarily viscous. Their behaviour therefore is very different from that of cementitious materials for which the effects of time, temperature, humidity and curing conditions are in general different. Thus, it is difficult to decide what properties are the significant ones.

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. However, the current lack of comprehensive data and suitable guidelines leaves some uncertainty as to how to proceed with the design and execution of durable repairs. Therefore, expert advice that helps to rationalise the many chemical and physical variables and multiple material choices for the intended job is certainly helpful to practicing engineers. In many instances, such advice provides a methodical approach to material selection and can help reduce the installed cost of many repair jobs.

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