CEMENTITIOUS MORTARS AND GROUTS

INTRODUCTION

The purpose of this Technical Note is to highlight various technical requirements which are considered fundamental to the satisfactory use of cementitious mortars and grouts as part of concrete repairs, grouting of post tensioning ducts, filling soil nail wall holes, grouting beneath base plates of sign structures and for constructing bridge bearing pedestals for beam support. Cementitious based mortars and more particularly polymer modified cementitious mortars have basically replaced epoxy mortars for concrete repairs due to their overall compatibility with the parent concrete compared to the resin based products. Resin based mortars may however, be used where appropriate for small scale repairs and where resistance to chemical attack or rapid initial strength gain is required.

The polymer modified cementitous mortars are high performance repair materials which work monolithically with the parent concrete due to their similar physical properties such as modulus of elasticity and coefficient of thermal expansion. Other good attributes include extremely low shrinkage rates (shrinkage compensated) which allow them to maintain excellent bond strengths, low permeability (breathability), good durability and ease of application ([1, 2, 3, 4, 5]). More importantly they offer alkaline protection to the steel reinforcement by the cementitious based matrix. In addition, most polymer modified cementitous mortars exhibit a high resistance to diffusion by carbon dioxide, chlorides, water and water vapour and other chemical attack. Cementious mortars are also lower in cost than resin mortars. Epoxy and synthetic resins are products of the petrochemical industry and their cost compared to traditional materials is relatively high.

Free flowing cementitious grouts and fluid microconcrete are part of further developments into cementitious repair materials and application techniques which are very useful for extensive and large scale repairs where access for hand/trowelled mortars is difficult. The use of cementitious grouts would invariably require the fixing of tight formwork onto the old concrete and the free flowing grout or fluid microconcrete subsequently pumped or hand poured in the prepared formwork.

TYPES OF CEMENTITIOUS MORTARS

Site proportioned unmodified sand and cement mortars are subject to considerable variability, associated mainly with the accuracy of proportioning, variability in characteristics of materials themselves, and site practices and procedures. In addition, it is extremely difficult to incorporate accurately special additives or admixtures to provide shrinkage compensation, low permeability, workability and overall ease of application. As a result of this degree of variability, significant developments have taken place over the years in the formulation of various unmodified and polymer modified cementitious materials which help to overcome the above problems, and lead to greater consistency in achieving a successful repair. The formulation of such proprietary materials has developed from specially formulated mortars and grouts, to polymer dispersions added on site, to two part pre-packaged systems blended on site, to the more effective advancements of one part (single component) pre-packaged formulated mortars. Obviously this overcomes the site batching and blending on site and has the potential to achieve optimum performance if the appropriate application methods are followed. A major advantage of prepacked cementitious mortars and in particular single component mortars is that they are produced under factory controlled conditions with strict quality control procedures, and they are convenient and easy to use.

Although different cementitious materials have slightly different properties from each other, they still have very compatible properties to the parent concrete. Epoxy resin mortars on the other hand are physically very dissimilar to concrete, having a lower value of modulus of elasticity and considerably high coefficients of expansion, compressive strength and impermiability. These disparities can induce high stresses at the interface of the repair and the parent concrete if the shear stresses exceed the tensile resisting stress of the parent concrete, thus causing subsequent debonding of the repair. Therefore, although epoxies possess superior compressive and tensile strengths they will not give monolithic performance.

CEMENTITIOUS MORTARS OF TROWEL APPLIED CONSISTENCY

A significant number of commercially available trowel applied proprietary materials are available in the general market.

Trowel applied mortars (Fig. 1) exhibit a variety of advantageous properties and in general are designed for ease of on-site application under a range of in-service conditions. In particular they are characterised by suitable consistencies and adhesion which assist in the application of a range of build thicknesses and thus significantly minimize the amount of formwork required. In general, trowel applied cementitious materials range from mortars with some formwork requirements, to high build cementitious materials which can be applied in layers of up to 80 to 100 mm in both vertical and overhead surfaces, without the need for formwork. The use of trowel applied mortars and indeed the use of other materials in other methods of application, in large or small patch repair of damaged reinforced concrete, normally represents only one stage in a sequence of application of materials, forming a comprehensive repair system. Full details of a repair process are presented in Technical Note No. 72[6].

In general, trowel applied materials should be used within the pot life of the product. They should be compacted into the primed substrate and around steel reinforcement with a wooden or steel float, pressing the mortar firmly into the bonding coat to ensure adequate adhesion. In areas where application by trowel is difficult (such as areas congested with steel reinforcement), the mortar should be applied and compacted by gloved hands, ensuring that each layer is properly kneaded into previous layers and no weak interface is produced. Where larger areas are being repaired, a screed board or straight edge can be used to finish the surface. If subsequent layers are required some time later, the preceding layer should be left roughened to provide a mechanical key. Priming should always be carried out between layers. Depending on the type of surface texture required, these repairs are finished by striking with a straight edge, or finished with floats (wood, steel, plastic) or sponges.

CEMENTITIOUS NON-SHRINK GROUTS

These are single component proprietary highly flowable grout used where repairs are extensive and access for mortar application is difficult, such as spalled piles or piers in splash zone area. In these cases, repair concrete may be applied as fluid grouts pumped or poured into formwork placed over the repair. Single component proprietary highly flowable grouts can also be used for grouting post tensioning ducts, for filling soil nail wall holes, for grouting beneath base plates of sign structures (Fig 2), and for constructing bridge bearing pedestals for beam support. These grouts generally exhibit low water/cementitious material ratio, low permeability, high strength and virtually no shrinkage and have the advantage over normal superplasticised concrete of offering greater reduction of bleeding or segregating, especially where steel reinforcement is congested and some of them have the capability of flowing over long distances without any adverse effects. Due to the free flowing and non-shrink characteristics, the materials used are very workable and self-compacting. Free flowing grouts should be fed in the formwork from the lowest or farthest point to ensure the exclusion of all air voids. Although many cementitious grouts offer a non-shrink capability in the plastic state, some higher performing grouts also offer a non-shrink capability both in the plastic and hardened state together with high flowability and higher performance.

It is considered that bridge bearing pedestals should be constructed utilising high performance, self consolidating and self levelling, dual shrinkage compensating (both in the plastic and hardened state) cementitious grouts. It should be noted that in many cases conventional concrete can not be used to satisfactorily construct bearing pedestals due to the impracticability to satisfactorily compact shallow pedestal thicknesses with an insertion vibrator. In many cases such pedestals may remain uncompacted if constructed with conventional concrete which is technically unacceptable and not conducive to long term durability as required by specifications. Furthermore, high performance grouts can assist with the development of high early compressive strength where early loading of the bearing pedestals may be required.

HANDLING AND STORAGE OF MATERIALS

Cementitious materials should be stored in dry conditions not exposed to direct sunlight, in strict accordance with the material manufacturer's data sheet requirements and within the manufacturer's specified maximum and minimum temperature range. It is also important that materials remain in their original, sealed moisture resistant bags or containers until time of use to ensure the quality of performance required ([1, 3, 6]).

All material should be brought to site in the original sealed bags or unopened containers and should be labelled with the appropriate manufacturer's name, product type, reference number and batch number. All cementitious materials should be used in the order of date of manufacture (from earliest to latest) and any materials stored beyond the manufacturer's recommended shelf life should not be used.

CURING AND PROTECTION

Cementitious mortars and grouts require curing in accordance with good concrete practice (Fig 1). This is essential both to develop the impermeability of the in-situ materials and to reduce the stress of drying shrinkage to a minimum while bond strength is developing. More specifically the cementitious material should be applied and cured in accordance with good curing practices such as with a curing compound in accordance with the material manufacturer's specification and Section 689[7]. Curing compounds should comply with the requirements of AS 3799([1, 3, 6, 7]).

The repair material should be cured and protected from drying out and against the harmful effects of water movement and weather, including rain and rapid temperature changes for a minimum of 7 days after placing.

COMPRESSIVE STRENGTH OF CEMENTITIOUS MATERIAL

The compressive strength of cementitious mortar and grout material should be tested by procuring test cube samples at a prescribed frequency (Fig. 3). In general three, 75 mm test cubes should be taken from the first batch of material mixed, cured and tested in accordance with AS 1478.2, followed by three, 75mm cubes for every 100 kg of material used thereafter. The cubes should be cured for 7 days under laboratory-controlled conditions. Two cubes should be tested at 7 days and the third cube at 28 days to confirm compliance with the minimum compressive strength requirements as shown on the manufacturer's material data sheet or as required by Section 689 whichever is applicable.

RAPID SETTING CHEMICALLY REACTIVE MORTARS

Intended use

Rapid setting chemically active mortars include Magnesium Phosphate cement mortars which are based on special types of hydraulic cement. Magnesium Phosphate cement mortars are involved in high exothermic reactions and as such generate a significant amount of heat and rely on air curing to develop their optimum properties compared to normal cementitious materials which require good curing practices. The high heat of hydration can cause thermal cooling stresses. Such materials produce high early strength and appear to be best suited to sliver spalls and pop outs and for emergency work where availability of time is limited and putting an asset out of service for extended periods is unacceptable.

Reactivity with zinc and other materials

It has been previously established that some proprietary materials such as the highly alkaline Magnesium Phosphate cement mortars when used as bedding or levelling mortars for galvanised base plates of railing systems or generally when they come in contact with galvanised materials, react with the galvanising in their wet state prior to setting, thus etching it away. Essentially the highly alkaline mortar, in the wet state, reacts with the zinc of the galvanising layer, including the evolution of hydrogen at the interface. The zinc is lost, leaving the steel unprotected. The steel base plate subsequently suffers corrosion in the presence of moisture and oxygen, often producing staining and spalling.

The problem was first identified and reported some time ago with Magnesium Phosphate cement mortar (i.e. Set 45) which was found to react with zinc, aluminium and galvanising materials, resulting in a loss of adhesion at the repair interface and causing etching of the surface of the metal.

The problem was also identified again in the early 1990's on some completed projects, including the Bell/Banksia project and pedestrian bridges on the Western Ring Road, where rust stains were observed at the base plates of railing systems. As a result some costly remedial measures had to be undertaken.

Other proprietary products which may affect galvanizing, zinc or aluminium usually contain admixtures and accelerators such as calcium chloride used for fast setting purposes.

Recommended Solutions

It is recommended that when it is proposed to use proprietary mortars as levelling, repair or bedding mortars in contact with galvanized base plates or in general contact with any other galvanised, aluminium of zinc plated steel, users should seek to establish the compatibility of these materials with the relevant manufacturers. Alternatively, contractors should be required to submit manufacturers' certificates which support that such proprietary materials are compatible with galvanised, aluminium or zinc coated materials. It should be noted that some manufacturers flag such a potential problem in the relevant material data sheets.

Other limitations

Magnesium phosphate cement mortars in their wet state may also react with the carbonated zone of concrete substrates to produce carbon dioxide and thus cause a reduction in bond strength at the bond interface. As such concrete substrates must be well prepared by mechanically removing the carbonated layer of the parent concrete prior to the placement in position of such chemically active mortars.

SPECIFIC CRITERIA FOR SELECTING CEMENTITIOUS REPAIR MATERIALS

Specific factors that contribute to the selection of a particular concrete repair material are as follows:

a) Thickness of the repair section would contribute to cementitious material selection
   - some cementitious materials shrink excessively if placed in thick layers
   - some may spall off if placed in thin layers
   - some do not have good adhesive characteristics for subsequent layers
   - consider feather edging.

b) Moist Conditions
   - some materials do not cure in moist conditions (i.e. magnesium phosphate cement mortar)
   - whereas some may be moisture insensitive.

c) Prevailing Temperatures
   - some materials are good at low temperatures
   - some are good at high temperatures
   - some have good all round performance.

d) Vertical or Horizontal Repair
   - shotcrete/gunite.

e) Life Expectancy of Material
  - if repair has small life span may be able to use cheap material.

f) In Service Temperature
  - expected temperature variations
  - coefficients of thermal expansion.

g) Appearance
  - colour matching requirements
  - some materials are unsuitable.

h) Exposure to Aggressive Environments

i) Exposure to Vibrations

j) How soon is repair required?
  - subject to early loading
  - rapid strength is essential.

Furthermore, the following properties are generally required from repair materials in order to ensure a successful and long lasting repair:

- Good bond to parent concrete.
- Similar shrinkage, thermal and wetting/drying movement to the parent concrete.
- Ability to passivate the steel reinforcement.
- Low permeability to aggressive agents such as carbon dioxide and chlorides and corrosion facilitating agents such as oxygen and water.
- Durability and resistance to chemical attack and weathering.
- Similar strength (and similar modulus of elasticity).
- Ease of application.

Fig 1: Trowel applied cementitious mortar (L), Cementitious mortars and grouts require curing in accordance with good concrete practice (R)

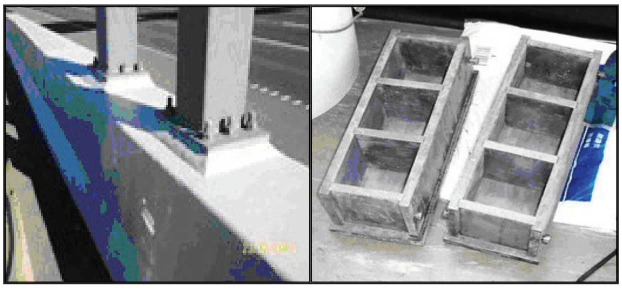

Fig. 2: Grouting beneath base plates of sign structures (L), Steel cube moulds for sampling mortars and grouts (R)

Fig. 3: Making of cementitious mortar and grout test cube samples with exposed surface cured with the application of a curing compound (L), Test cube samples awaiting transportation to the laboratory for curing under laboratory-controlled conditions and subsequent testing for compressive strength (R)

REFERENCES

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