Repair of Concrete

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INTRODUCTION

HARDENED concrete is a strong and durable material. However under certain situations, it deteriorates through scaling, spalling and cracking over a period of time. The important factors which contribute towards deterioration are :

i) use of sub-standard and faulty materials.
ii) improper concrete mix design.
iii) bad workmanship.
iv) insufficient curing.
v) alkali-aggregate reaction.
vi) sulphate and other chemical attacks.
vii) corrosion of steel reinforcement.
viii) drying shrinkage of restrained members.
ix) thermal changes leading to expansion and contraction of concrete (mass concrete constructions).
x) settlement of foundations.
xi) overloading, either due to faulty construction or from imposition of a greater load than that for which the structure was designed.
xii) expansion of metal embedded or fixed to concrete subjected to heat from boilers or furnaces (industrial structures).
xiii) mechanical abrasive action.

Before taking up repair of the damaged concrete, it is important to determine the cause and the extent of the damage and to establish that a larger portion of the structure requiring repair is of suitable quality. It is equally important to determine the degree and extent of repair required. Here the engineer has to draw upon his experience and mature judgement by taking into consideration various factors enumerated above. If the damage is due to moderate exposure of what was an inferior concrete in the first place, then replacement by acceptable concrete would assure enduring results. But if the damage is the result of an exposure so severe that a high quality concrete is destroyed, then the solution becomes more complex. In this case, an even better quality of concrete is needed or exposure conditions (drainage conditions, provision of mechanical protection for structures such as bridge piers, etc.) has to be suitably modified.

GENERAL REQUIREMENTS FOR REPAIR

In concrete repair the usual materials and tools of concrete construction are employed but with a certain refinement of procedure which experience has taught is necessary for good results.

Good serviceable repair should have the following characteristics :

i) a complete and permanent bond with the older concrete.
ii) sufficient impermeability to prevent moisture penetration to the under-lying older concrete.
iii) absence of drying shrinkage cracks through which water could reach the base concrete.
iv) sufficient resistance to freezing where this is a factor in weathering.
v) a good matching appearance in relation to the surrounding concrete surfaces

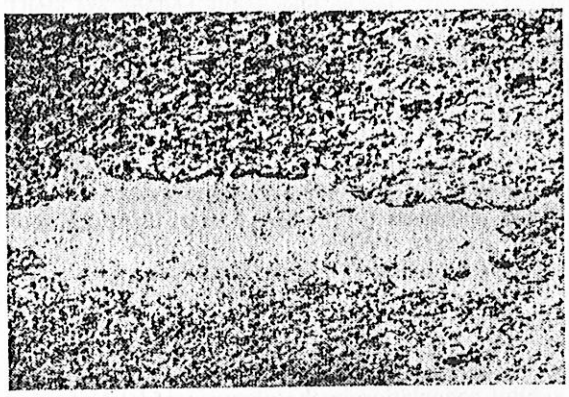
The first step to obtain a well bonded repair is preparation of the older concrete. This involves :

a) Removal of all unsound, deteriorated or defective concrete. Any questionable or semi-sound concrete must be removed until there is no doubt that the quality of the remaining concrete is satisfactory.
b) Shaping the excavation in such a way as to make the replaced concrete most secure. Excavation of the affected areas should continue until sound concrete is reached. Additional chipping may be necessary to obtain a satisfactory depth (usually 15 cm or more) and to shape the cavity properly. In a vertical surface the cavity must conform to the following requirements :
   i) sharp edges at perimeter of cut.
   ii) vertical sides and horizontal top at the surface of the member. The top line of the cavity may be stepped.
   iii) inside faces generally normal to the formed surface, except that the top should slope up towards the front at about 2.5 cm to 7.5 cm slope.
   iv) keying for locking the repair into the structure.
   v) sufficient depth to reach at least 2.5 cm behind any reinforcement.
   vi) all interior corners rounded with a radius of 2.5 cm.

In case of horizontal repair work, the only requirement is that the edges at the perimeter are sharp.

c) Cleaning of the older concrete surfaces.

Considerable amount of stone dust gets deposited on excavated surfaces during chipping and trimming. It should be thoroughly removed by scrubbing with a



Scaled Surface of a Concrete Slab.

wire brush. Wet sand blasting followed by final cleaning with an air-water jet or high pressure water nozzle is more effective and therefore preferable.

METHODS OF REPAIR

The concrete gets damaged through scaling, spalling or cracking. Different methods as described below are adopted to repair damaged concrete. The choice of the method depends largely upon the size, depth and area of the repair required.

1. CONCRETE REPLACEMENT METHOD

This method consists of replacing the defective concrete with fresh concrete of suitable mix proportion and consistency. It is suitable for repairing (a) through holes and other defects which go beyond the reinforcement, (b) scaled surfaces, (c) spalls and (d) cracks. It is also employed for repairing honeycomb in new concrete work soon after stripping of the forms.

(a) Repair of Through Holes

For repair of through holes and other defects which go beyond the reinforcement and for massive repairs in vertical surfaces, forming will generally be required. The forms should be strong and watertight. While the back form may be assembled in one piece, the front panel should be in pieces and built as concreting progresses. This facilitates placing of concrete in lifts not more than 25 cm in depth. Dowels and reinforcement are usually put in to make the patch self-sustaining and to anchor it to the underlying concrete so as to provide an additional safety factor.

Opinion is divided whether the surface of the older concrete should be wetted or not before placing the new concrete. According to the old practice, the surface should be kept wet for several hours, preferably overnight. More recent work, however, indicates that an equally good bond and possibly more permanent bond is obtained when the joint surfaces are dry. It is opined that the efforts spent on moistening before repair can better be spent on more water curing afterwards. On this basis, preparatory wet sand blasting should be done early enough for the surface to become dry again.

It is necessary to treat the dry contact surface suitably to obtain good bond with the new concrete. The best method is to shoot in a thin layer (not exceeding 3 mm) of cement — sand mortar pneumatically. Wire brushing or rubbing in by rubber gloved hands is also effective. The mortar should be prepared using sand passing 1.18 mm IS sieve (BS sieve no. 14). It should be proportioned as in the replacement mix and soft enough to work well into the surface. Other bonding materials used to treat the dry contact surfaces are :

i) neat cement paste.

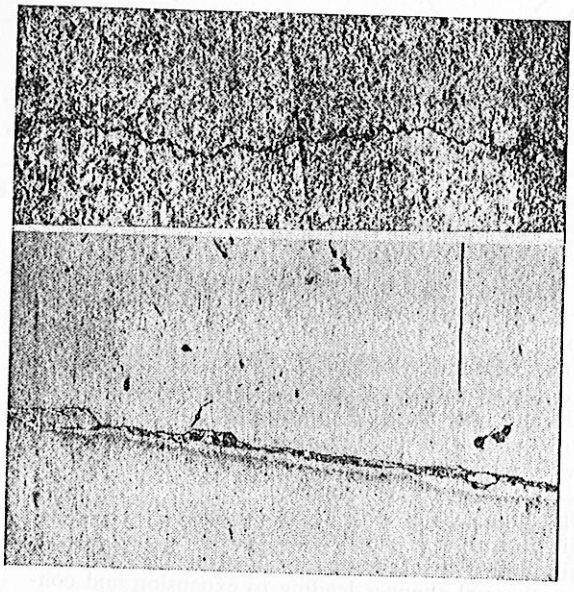
ii) epoxy resin of suitable formulation.

The epoxy resin is waterproof and highly resistant to chemical and solvent action. The bond obtained with it has greater tensile, compressive and shear strength than concrete. Its major disadvantages are its toxity, short pot life and high cost.

iii) polyvinyl acatate emulsion or dispersion.

iv) butadiene or styrene copolymer stabilized to inhibit coagulation in the presence of cement.

The bond developed by no. (iii) and (iv) bonding



Top Photo shows a cracked concrete surface. Bottom photo shows a spalled joint.

materials become weak on exposure to moisture. Therefore these materials should be suitably compounded with certain ingredients to render the dried film moisture resistant.

The concrete repair should be done immediately after the application of the bonding material over the dry contact surfaces of the old concrete. The concrete for repair should be prepared using maximum size of aggregate and water/cement (W/C) ratio similar to the old concrete. When the W/C ratio used in the old concrete can not be found out, then the slump of the concrete should normally be between 5 to 7.5 cm. except for the concrete used in the top few centimetres. The top layers of concrete should be placed at a lower slump. Each lift of concrete should be thoroughly vibrated, using internal vibration where accessibility permits. At least 30 minutes should elapse between lifts. A small amount of aluminium powder (2 or 3 g per bag of cement) is sometime added in the concrete mix to produce expansion for obtaining a tighter patch. In this case, there is no delay between lifts and no vibration subsequent to filling of the cavities with concrete.

Prepacked concrete which is produced by first placing the coarse aggregate in the forms and thereafter filling the voids by pumping sanded cement grout may be advantageously used for repair of damaged concrete in dams, tunnels, retaining walls, bridge piers and abutments, and reinforced concrete columns and beams in bridges and buildings. It bonds well to old concrete and has low drying shrinkage.

For proper development of strength, the new concrete should be adequately cured. Under normal summer conditions, moist curing for 7 days is considered adequate.

b) Repair of Scaled Surfaces

Scaling or surface deterioration in concrete slabs can be satisfactorily repaired by a thin concrete overlay firmly bonded to the old base concrete. The method of repair adopted is as follows :

All damaged or unsound concrete is mechanically removed. Further excavation may be required to produce a minimum overlay thickness of about 3¾ cm needed performance.

After the removal of the damaged concrete and excavation to the desired depth, the surface is thoroughly cleaned using an air-water jet or high pressure water nozzle, followed by a uniform application of commercial hydrochloric acid (18 deg. B, 28% HCl) at the rate of 3875 cc over about 6.7 sq m (1 gal over about 8 sq yd) of surfacing. Where the scaled surface is sound and no mechanical removal is required an acid etch is the only treatment needed. After etching and when the foaming has ceased, the residue and partially loosened sand grains must be completely removed by washing and vigorous brushing.

For perfect bond the concrete surface should be dry at the time of repair (except where zero slump concrete is to be laid). If the concrete has been dry for a long time, then slight wetting of the surface may be done but it should be allowed to surface dry before taking up repair.

Before placing the new concrete, a 3 mm thick layer of 1:1 cement-sand grout containing sand passing 1.18 mm IS sieve (BS sieve no. 14) should be thoroughly broomed into the concrete surface to coat it uniformly. The grout should not be spread so far ahead that it changes colour (due to drying) before the concrete is placed. In hot dry weather the old concrete surface should be wetted lightly just before grouting. Any of the other bonding materials mentioned earlier can also be used for treating the old concrete surface.

High quality concrete, preferably air entrained, should be used in the overlay with the maximum size of aggregate usually between 1/3 to 1/2 (one-third to one-half) of the minimum thickness of the repair. The mix should have about 2.5 cm slump and it should be carefully hand tamped or vibrated into place. The repair should be finished so as to match the texture of the surrounding concrete. Joints in the underlying concrete should be extended through the overlay to avoid cracking. The freshly laid concrete should be properly covered with wet gunny bags, burlap, etc., for the first day to prevent early drying shrinkage, which would otherwise adversally affect development of good bond. Afterwards it could be cured by occasional sprinkling or ponding of water at least for 3 days under normal summer conditions.

c) Repair of Spalls

Spalls most commonly occur adjacent to joints in concrete pavements. These are repaired by methods similar to those recommended for repairing scaled surfaces; the principal difference being in the depth of repair. Spalls usually are quite deep and even deeper excavation may be required to remove all concrete which has undergone even slight deterioration.

Epoxy resin can be effectively used to repair spalls. It may be used merely as a bonding coat in place of cement grout layer followed by a conventional concrete patch or it may be used in the patching material itself as a binder in place of portland cement to make an epoxy mortar or concrete. As in the case of conventional concrete patches, all unsound concrete must be excavated and the surface must be thoroughly cleaned preferably by sand blasting. The concrete surface should be dry at the time it is repaired. The film thickness of epoxy adhesive should be about 3/4th mm. When the repair is done using epoxy concrete, the mixture should be tamped into place and the surface finished by trowelling. The curing is done by maintaining the temperature specified for the chemical reaction to take place.

As mentioned earlier, epoxy resin mixes are rather expensive. They require careful attention to mixing and are difficult to place and finish. Safety precautions are necessary because of their toxic nature. For best results repairs should be done by personnel experienced in the use of epoxy materials.

d) Repair of Cracks

For the purpose of repair, cracks can be categorised in the following two groups.

i) those requiring only sealing against the intrusion of foreign materials.

ii) those where restoration of structural integrity is required.

The decision as to whether a crack should be merely sealed or treated so as to restore structural integrity can be made only after carefully considering the cause of the crack and nature of the structure. If the stresses which caused the cracks have been eliminated through cracking then structural integrity can be restored almost permanently. If on the other hand cracks, such as pavement cracks, have been caused by high sub-grade friction or vertical movement of the supporting earth structure then efforts spent on repair other than by sealing are of little value. In repairing any crack or joint all loose concrete, pebbles, dirt, old concrete joint sealer and other foreign materials must first be thoroughly removed using compressed air or by means of picks or similar tools. Sealing of accidental cracks without restoration of structural integrity requires materials and techniques similar to those used in filling designed cracks. Materials include asphalt, modified polysulfide polymers and rubber-asphalt fillers. These are applied either cold or hot.

Restoration of structural integrity can be achieved by repairing cracks with epoxy resin of suitable formulation.

2. PNEUMATICALLY-APPLIED MORTAR METHOD

This method is economical, convenient and has been found effective in repairing shallow, large and irregular weathered portions of vertical or sloping surfaces of hydraulic and other structures such as walls, spillways, piers and bridges. It can also be used for repairing horizontal surfaces. Normally a cement-sand mortar of 1:4 composition is used. As in the case of all concrete repair work, the damaged concrete should be completely removed to ensure that the mortar is applied on a sound and durable base concrete. On

vertical and sloping surfaces the repair can be done in one layer if the thickness does not exceed 1.25 cm. When the thickness exceeds 1.25 cm, then the repair should be done in successive layers at about 30 minutes interval to avoid sagging and loss of bond.

Repairs to horizontal slabs can be placed in layers upto 5 cm thick. When repairing surfaces over reinforcing bars, holes of varying depths or irregular imperfections, care must be taken to vary the angle at which the mortar gun is directed to ensure complete filling of all voids and to provide good bond. Where repair of relatively large areas of depths greater than 5 cm is required it is advisable to place a steel mesh dowelled to the base concrete.

After placing mortar pneumatically, keep it moist for the first day to prevent surface drying which will otherwise cause cracking. Subsequently wet curing for 5 to 7 days is considered adequate for the development of proper strength.

3. DRY PACK METHOD

Dry pack is usually a mix of 1 part cement and $2\frac{1}{2}$ parts of sand passing 1.18 mm IS sieve (BS sieve no. 14), by weight or volume. It has dry consistency. The quantity of water added is just sufficient to hold the mortar in the form of a ball formed by a slight pressure of the hands. It is placed and packed in layers having a compacted thickness of about 10 mm. Each layer should be compacted hard over its entire surface using a hardwood stick and hammer. Metal tempers should not be used as they are likely to polish the surface and the polished surfaces do not bond well.

Because of the dry consistency, the dry pack has practically no shrinkage. It develops strength which equals or even exceeds that of the old concrete being repaired.

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