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TENTATIVE GUIDELINES
FOR
REPAIR OF CONCRETE PAVEMENTS USING SYNTHETIC RESINS

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TENTATIVE GUIDELINES FOR REPAIR OF CONCRETE PAVEMENTS USING SYNTHETIC RESINS

1. INTRODUCTION

1.1. Necessity of repairs to cement concrete pavements arises either from imperfections in workmanship during construction, or as a result of subsequent damage or deterioration. In certain cases conventional methods of repair using bituminous materials may not give good results in all cases, and repairs with bonded cement concrete may be very time-consuming due to the long curing period involved. Synthetic resins provide an expeditious alternative in such cases. Thermo-setting synthetic resins of epoxy and polyester type can be successfully used for this purpose, as they combine the properties of rapid hardening, good adhesion, toughness, good strength, superior chemical resistance, etc. Concrete pavements repaired with these resins can be opened to traffic within 12 hours. Synthetic resins will also be found useful for speedy repair of cement concrete wearing courses on bridge decks.

1.2. Because of high cost-synthetic resins are however not to be regarded as a primary construction material like cement concrete or any other conventional material. Their most important function is for emergency repair of concrete pavements, especially in case of localised surface rectification, where no known cheaper material will give the desired performance or speed of execution. For such repairs, they will also prove more economical as compared to the alternative of providing the entire surface with a resurfacing layer.

1.3. Synthetic resins and their curing agents are allergenic, and safe handling practices must be exercised in all resin work. The mixing sequence for various resin components stipulated by the manufacturer should be strictly adhered to, as intermixing in the case of some of the components could cause explosion. User should obtain pertinent information in this regard from the manufacturer and comply with it fully. While the operations involved are basically simple and could be learnt easily, trained personnel and strict quality control are desirable to ensure proper results.

1.4. These guidelines were approved by the Cement Concrete Road Surfacing Committee (personnel given below) in their meeting held at Calcutta on the 18th December 1977.

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These were processed by the Specifications & Standards Committee in their meeting held at New Delhi on the 6th November 1978 subject to certain modifications which on the authorisation of the Committee were carried out by Dr. R.K. Ghosh, R.P. Sikka and B.R. Govind, assisted by Y.R. Phull, K. Arunachalam, M. Dinakaran and C.S. Pant. These were later approved by the Executive Committee and the Council in their meetings held on 24th April and 28th October 1979 respectively.

2. MATERIALS

2.1. Synthetic Resins

2.1.1. **General:** Synthetic resins are multiple-component systems, comprising of the main resin component and its curing agents which may be variously termed as hardeners, accelerators, catalysts, etc. When stored separately, resins and their curing agents retain their properties for a certain period after manufacture which may vary from a few months to a year or more for different resins. This period, which represents the useful storage life of the resin is known as its "shelf life". On mixing the components together, the resultant "resin formulation" rapidly starts becoming more and more viscous, and under average temperature conditions, becomes unworkable and unfit for use after 30-45 minutes. The period upto which a resin formulation is usable after intermixing of the components, is called its "pot-life". As synthetic resins are thermosetting, their pot-life decreases with increase in temperature. At low temperatures, while pot-life prolongs, development of strength would be slower.

Synthetic resins of epoxy and polyester group are normally employed in concrete pavement repairs. Epoxy resins are of different types, the prominent ones being diglycidyl ethers of diphenylol-A ('A' may be propane or any other group), epoxy novolacs and chloroaliphatic epoxies. The hardeners used with epoxy resins are polysulphide polymers, polyamide and amine adducts. The common curing agents are aliphatic or aromatic amines. Chemically the term "epoxy" means a three membered ring containing one oxygen and two carbon arranged as

$$\begin{array}{ccccc} & H & & H & \\ & | & & | & \\ - & C & - & C & - H \\ & \diagdown & & \diagup & \\ & & O & & \end{array}$$

In a resin molecule, on an average, more than one epoxy group is present. The acute angle in the structure strains its chemical bond through interaction, thus making the three membered ring hardly reactive.

Polyester resins are reaction products of a polyhydric alcohol and an unsaturated polybasic acid. Unsaturated polyester thus formed possesses good adhesive properties. Catalysts used with polyester resins to start the reaction are usually peroxides or hydroperoxides. Besides catalysts cobalt naphthanate is used as accelerator to hasten the reaction started by peroxide.

2.1.2. **Factors affecting choice of the resin system:** As many resin systems of varying properties are available in each of the two broad resin groups, viz. epoxy and polyester, for any particular application the resin system to be used should be selected with due consideration of the following factors:

(1) **Location of use and its climate**—Different resin systems perform differently under varying climatic conditions and for different types of repairs. Some resin systems are more susceptible to moisture than others, and can be used only in hot dry climates. The range of annual temperature variation is important in selection of the resin system, as coefficients of thermal expansion of resin formulations are much higher than that of cement concrete. The thermal coefficient of resin-sand mortars reduces with increase in leanness of the mix, so that other things being equal, resin systems with somewhat lower thermal coefficients, and with lower viscosity which would permit use of leaner mixes, would be preferable in case of locations with high range of annual temperature variation. Polyester resins are highly susceptible to moisture and cannot be used in areas of heavy rainfall, high water table or water-logged pavements. They can be considered for use only in areas of temperate climate at locations not susceptible to moisture.

(2) **Ambient temperatures during the period of use**—Since pot-life of a resin system is temperature dependent, the resin system should be so selected that adequate pot-life is obtained for the expected ambient temperature during the period of use.

(3) **Type of repair**—In certain cases the type of repair to be carried out will also influence the choice of resin system. Thus, in case of resin-bonded cement concrete repairs, slow-setting epoxy systems (e.g. epoxy system with polyamide and amine adducts) non-susceptible to moisture are normally recommended. The use of polyester resins as bonding media between old and new concrete is ruled out on account of their high susceptibility to moisture. In case of repair of cracks by resin-injection, the low-viscosity resin systems would be desirable. For larger sized patch repairs, lower shrinkage coefficient is also helpful.

(4) **Bond between hardened cement concrete and resin mortar; and its durability**—Adequacy and durability of bond of the resin material with the cement concrete of the structure is essential for satisfactory repairs. In general, epoxy resin mixes have been observed to be much less susceptible to loss of bond with cement concrete under extreme climatic changes (temperature variation 90°C) vis-a-vis polyester resin mixes. Loss of bond is severe when the resin mortars are made with polyester resin and alkaline sand.

2.1.3. **Properties of resins and resin mortars**: For choice of the resin system under any service conditions, manufacturers' recommendations should be obtained. Among resins of different manufacture, final selection should be based on laboratory investigations of properties of the resin system, resin-sand mortars and cement concrete-resin mortar composites made therewith, especially in case of large-scale works. Following properties would normally need to be investigated:

(i) Pot-life of resin system

(ii) Compressive strength, and moisture susceptibility of resin-sand mortars

(iii) Bond strength of cement concrete-resin mortar composites

(iv) Shrinkage and thermal characteristics of resin system and resin mortar

(v) Durability of resin mortar-cement concrete composites.

Procedures for carrying out the above tests are given in *Appendix 1*. Typical values for different properties of resin systems of epoxy and polyester groups are given in *Appendix 2* for information.

Where the magnitude of the work is small and testing facilities are not available, selection may be made on the basis of the considerations indicated in para 2.1.2, in conjunction with the information obtained from suppliers/manufacturers (vide para 2.1.4) and their recommendations. As an aid to selection, some typical resin formulations, and the uses for which they may be considered, are given in *Appendix 3*.

2.1.4. **Information required from resin supplier/manufacturer**

(1) Nomenclature and proportions of the resin system components.

(2) Type of resin system.

(3) Storage and mixing directions.

(4) Hazardous potentialities and handling precautions.

(5) Usable temperature range.

(6) Shelf life.

(7) Available test data on resin properties, e.g. pot-life, thermal and shrinkage characteristics, viscosity, strength, moisture susceptibility etc.

(8) Adjustments in composition for change in temperature of use.

(9) Heat distortion temperature.*

(10) Other pertinent information, e.g. strength and durability characteristics of resin mortars and cement concrete-resin mortar composites (if available), suitability for conditions of use, viz. location, climate, type of repair, etc.

(11) Date of manufacture (to be indicated on the containers).

2.1.5. **Storage:** The various components of the resin system should be kept in tightly closed and appropriately labelled containers. As some of the components may be volatile and/or inflammable, the resins should be stored in a cool, covered, protected place, away from any naked flames. No smoking should be allowed in the vicinity of the resins. The date of manufacture and shelf life should be ascertained from the manufacturer for each lot of supply, and marked on the containers. After expiry of shelf-life, no material should be used without rechecking its quality through laboratory tests.

2.1.6. **Handling:** For repairs during hot weather, the resin components should be kept in shade and not in direct sunlight. Appropriate handling precautions should be ascertained from the manufacturer and their strict observance ensured. Adequate fire protection measures should be taken during mixing and placing operations. Smoking or use of spark or flame in the vicinity should not be permitted.

Good handling practice for resin materials and mixes requires:

(i) Working in a well-ventilated area (in case of laboratory tests).

(ii) Storing the resin materials below eye level.

(iii) Using disposable containers, equipment and gloves, wherever feasible.

**Heat Distortion Temperature* : is the temperature at which the chemical structure of the resin begins to change, adversely affecting its utility as a repair medium.

(iv) Using safety goggles when handling resin compounds.

(v) Avoiding accidental contact with or intake of resins. Habits like scratching of body parts or eye-glass adjustment should be avoided. When wearing soiled gloves, the worker should avoid touching door handles and other equipments which may subsequently be touched by persons not wearing gloves. After completion of work also, eating or smoking should not be done without washing up.

In the event of direct contact with resin, safety steps indicated below should be immediately taken :

Items of contact	Action required
Clothing	Remove the soiled clothing immediately.
Body	Wash immediately with soap and water to remove the resin compound from the body.
Eye	Flush out large quantities of water followed immediately by medical attention.

Note : For cleaning purposes, soap and water only should be used. Most of other solvents merely dilute the resin compounds and aid them in penetrating the skin.

Solvent used for cleaning up of equipment should not be used to remove resin products from the skin. They will tend to dry the skin and may cause dermatitis. Moreover, they dissolve the skin compounds and aid them in penetrating the skin, thus aggravating the problem. Some solvents contain aggressive chemicals which can cause burns or other serious effects on coming in contact with body parts.

Many solvents such as ketones have low flash point and present fire hazard, and call for adequate ventilation and fire protection measures. Some solvents are toxic when inhaled. Their use should be avoided.

There is no solvent material for removing set resin-formulations of both polyester and epoxy type from containers, mixing appliances etc. However unset resin from containers may be cleaned by :

(i) Mixture of equal proportions of ethyl alcohol and benzene

(ii) Mixture of equal proportions of ethyl alcohol and toluene

(iii) Toluene

(iv) Benzene

(v) Ethyl alcohol

Of the above solvents, (i) and (ii) are more effective. However, as these solvents are very costly, they should be used only when justified. In general it is advisable to use disposable containers.

2.2. **Aggregates**

In some applications, fine and coarse aggregates are used for economy or to improve the performance of such applications. Both coarse and fine aggregates should be clean, hard, strong and cubical in shape. Friable, flaky aggregates or sand should not be used. Alkaline aggregates should be guarded against, as they are known to affect resin repairs adversely. In all cases, the aggregates should be washed clean, and be absolutely dry and neutral at the time of use.

Coarse aggregate may be added in case of deep patch repairs only. The maximum size of coarse aggregate should be less than one-third the mean depth of the patch. It is neither desirable nor economical to use coarse aggregates larger than 25 mm size. For most applications, coarse aggregates fit for cement concrete are satisfactory for use in resin concrete. A wide range is feasible with regard to the grading of suitable fine aggregate for resin mortars. In general, aggregate for resin mortar or concrete should be uniformly graded. In resin mortars fine river sand passing IS 1.18 mm sieve and having a fineness modulus of about 1 can also be used. Some typical gradings recommended are shown in Table 1.

Table 1. Recommended Grading of Sand for Resin-Sand Mortars

I.S. Sieve Size	Fine Sand Per cent Passing	Medium Sand Per cent Passing
4.75 mm	100	100
2.36 mm	100	100
1.18 mm	100	100
600 micron	95—100	20—30
300 micron	90—100	50—60
150 micron	5—20	20—30

For better skid resistance of overlays for pavements, and for heavy-duty wear resistant floor toppings, special fine aggregate of abrasion-resistant type such as silica sand, hard crushed stone (e.g. trap), alumina, silicon carbide, or blast furnace slag should be preferred. For use in surface treatments, the material should be of medium-fine-size, usually between 2.00 mm and 600 microns. In case of resin mortar overlays, any of the gradings given in Table 1 may be adopted.

3. MIX PROPORTIONS

3.1. Resin Formulations

Proportions of the different constituents to prepare resin formulations should be fixed depending on the curing schedule and satisfactory pot life for outdoor work. Due consideration should be given to temperature conditions under which the work will require to be carried out, as well as the service conditions, including maximum and minimum temperatures, rainfall etc. which the finished work is expected to cater to. For polyester resins the quantity of accelerator should be between 0.5 ml to 1. 5 ml per 100 grams of resin for a mixing temperature of 40°C to 10°C while for epoxy formulations with tertiary amine as hardener, the quantity of the tertiary amine should be limited between 4 gms to 10 gms per 100 grams epoxy resin for temperature range 40°C to 10°C.

3.2. Resin Mortar and Concrete

In applications involving resin mortar or concrete, the mix proportions should be such that the resin formulation is adequate to fill voids in the aggregate and coat the aggregate surface completely, while producing a mix of appropriate consistency and satisfactory finishing properties. In resin mortars, generally one part by weight of resin formulation is mixed with 3-5 parts by weight of medium to fine sand. In case of resin concrete using larger maximum size of aggregate, the proportion of aggregate to resin formulation could be as high as 8:1 (by weight) for aggregates in the specific gravity range of 2.5 to 2.8.

Since the viscosity of the resin formulation at the temperature of use affects the aggregate/resin formulation ratio, the ratio will also be influenced by the choice of resin system selected for the application. For appropriate selection of the mix proportions, it is advisable to make trial mixes at a temperature slightly higher than the anticipated temperature at the time of application. If the actual field temperature varies significantly from the trial mix temperature, additional field trials should be made for necessary mix adjustments.

4. PREPARATION OF RESIN FORMULATION, MORTAR AND CONCRETE

4.1. Resin Formulation

The different constituents of the resin should be accurately proportioned, using suitable weighing or measuring devices. Special care is necessary in respect of constituents which need to be mixed in relatively smaller quantities as even a slight variation in their proportion could significantly affect the formulation characteristics especially with regard to pot life.

Thorough mixing of all the components of the resin is essential. For this reason, the resin components should be mixed in a container which has nearly hemispherical bottom, without any sharp corner or bends which may locally prevent proper mixing. The components are mixed by stirring or agitation to put them into solution effectively. For small quantities upto one kg., spatula, palette knife or similar device may be used for the purpose. For larger quantities, mechanical mixing device such as a rotating bucket type mixer or paddle type paint mixer driven by low-speed electric motor may be used. Mixing should be continued till the formulation is homogenous.

In case of manual application, the quantity to be mixed at a time should not exceed 2 kg., because of short pot life of the resins. Where the mixing and applications are mechanical, the quantity to be mixed at a time can be suitably increased. Wherever possible, small batches may be handled in disposable containers, because cleaning is difficult and costly.

4.2. Resin Mortar and Concrete

For preparation of resin mortar, fine aggregates are added to the thoroughly mixed resin formulation and stirred till all the aggregate particles are fully coated and the mix is homogenous. Manual mixing of resin mortars with the help of trowel should be restricted to a batch weight of 2 kg. For large batches, power driven cement mortar mixer may be used but should be immediately cleaned.

Resin concrete is prepared in the same manner as resin mortars. In case of relatively stiff mixes, the coarse aggregate should be added and mixed with the resin formulation first, followed by gradual addition of fine aggregates while mixing is continued. This sequence will help to prevent the tendency to "balling"* in the mix. Mixing should be continued till the mix is uniform.

5. TEMPERATURE CONDITIONING FOR HOT AND COLD WEATHER REPAIRS

5.1. Synthetic-resin systems cure with an exothermic reaction and are thermosetting. The rate of curing and the ease and effectiveness of application are greatly influenced by the temperature of the resin systems at the time of use, the temperature of

*Balling: If coarse aggregate is added subsequent to mixing of fine aggregate with the resin formulation, the coating of coarse aggregate with the resin is not uniform, some aggregate particles getting coated and some remaining almost uncoated. On the coated coarse aggregate more and more mortar gets adhered, leading to "balling". Balling makes the mix non-homogenous.

surface on which the synthetic resin system is to be applied, and the temperature conditions obtaining during curing. The conditions under which these systems are to be employed should be anticipated and appropriate provisions made in each application specification. Suggested provisions are given below.

5.2. Temperature Conditioning of Pavement Surface and Fresh Repairs

(a) Temperature lower than 10°C

When concrete and atmospheric temperatures are lower than 10°C, the temperature of cement concrete to be repaired should be raised upto a depth of 7.5 cm so as to accelerate the hardening rate of the synthetic resin system and gain early functional use of the area. The cement concrete temperature should be at least 15°C and preferably about 25°C, prior to application of the synthetic resin. Under cool weather conditions, an artificial environment may be created for this purpose, for instance by having an enclosure heated by circulating warm air, using a source of uniform radiant heat such as electric heaters, or lighting 1000 W electric bulbs in suitable enclosures. In any event, localized heating should be avoided and heat provided in such a manner that the surface temperature stays below 40°C during the hardening period.

(b) Temperature lower than 25°C and above 10°C

In this range of temperature, repair work with synthetic resins can be accomplished satisfactorily without creating an artificial environment provided a suitable formulation for low temperature curing is employed and a somewhat increased hardening period can be tolerated.

(c) Temperature exceeding 35°C

When the temperature of cement concrete surface being repaired and atmospheric temperature both exceed 35°C, difficulties may be experienced in mixing and application owing to acceleration of hardening rate of the synthetic resin system. In these cases work should be scheduled when the temperature is usually lower, for instance in early morning hours, or the areas of repair should be protected from direct sunlight prior to and during the application operations.

5.3. Temperature Conditioning of Materials

Regardless of weather conditions under which the application is made, it is advisable to condition the components of resin formulation to 25°C to 35°C prior to mixing. A simple method is to store the components indoors in a heated room overnight and to remove them therefrom shortly before use. A quicker method will be to keep the compounds in a heated enclosure or immerse them in their containers in a hot water bath. When cooling is required to provide adequate working life, the components can be stored in shade or containers can be immersed in a bath of cold water. While the manufacturers' instructions should be followed, in general the compounds should not be heated beyond 60°C or cooled below 15°C.

Aggregates to be used in resin mortar or concrete should be similarly conditioned to a temperature of 25°C to 35°C. Like the resin components, they may be warmed by storing in a heated room or enclosure, or with the help of radiation. For cooling, the aggregates may be spread into thin layers or stored in the shade. These should not, however be cooled to the extent that mixing with resin becomes difficult or condensation of moisture from the air takes place.

6. SURFACE PREPARATION

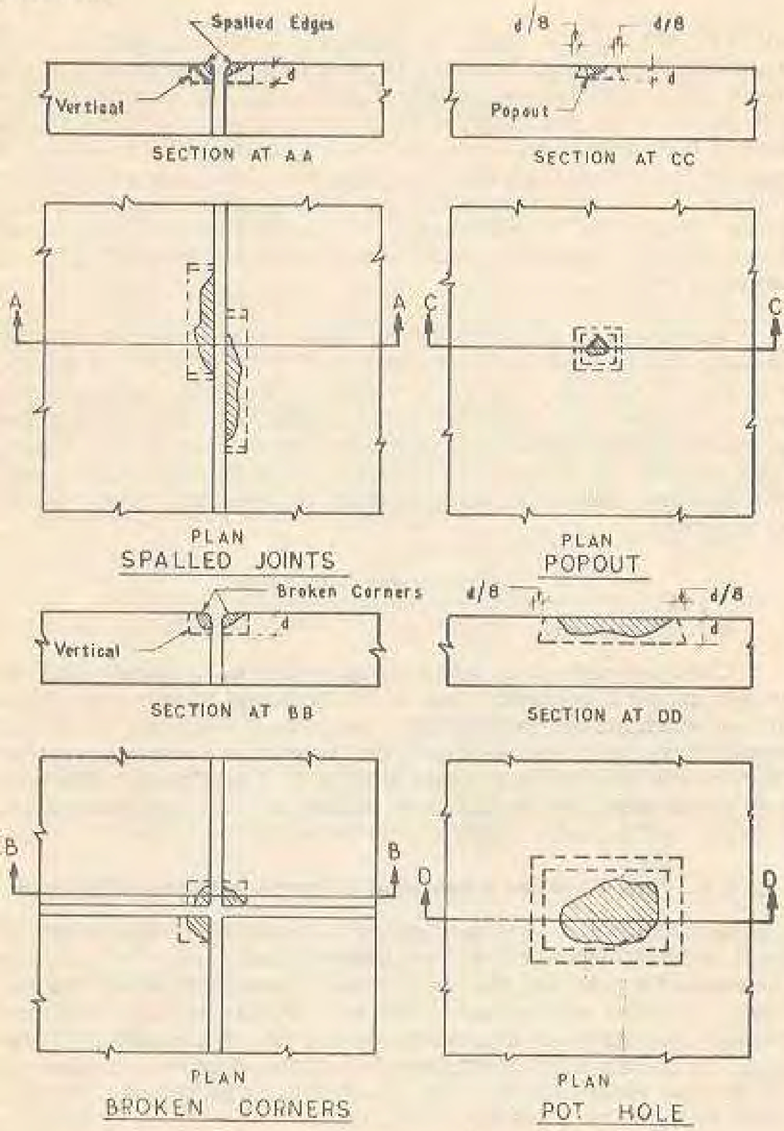
6.1. General

Concrete surface to which resin is to be applied must be freshly exposed concrete, free of all loose and unsound materials. The surface must be meticulously clean and dry, and at proper temperature (vide para 5.2) at the time of the resin application. Care must be taken that moisture does not rise through the concrete due to capillary action and collect at the interface of the concrete and the resin during curing period of the latter.

6.2 Case I—When Removal of Concrete in Depth is Involved

For removal of loose and unsound concrete in depth, use of chisel and hammer manually or pneumatically can be adopted. The recess for receiving the resin mortar or concrete should be formed to a regular geometrical shape, with its side parallel and perpendicular to the joints in concrete pavement. If possible, the side should be given a slight slant so that the base of groove so formed is somewhat wider than the top to ensure better keying for the repair work. This is illustrated in Fig. 1.

The top edges of the groove should be carefully chiselled manually to make them as straight as practicable, and give the finished patchwork a neat appearance. If a joint cutting machine is available, 1-2 cm deep peripheral cuts at the top can be made initially



Notes — 1. Dotted lines show the regular grooves to be formed for repairs.

2. For repairs with resin mortar d ≯ 5 Cm.

Fig. 1. Preparation of surface groove for resin repairs of popouts, pot-holes and corner and edge spalling

with the same, and the concrete within subsequently removed to the required depth by chiselling. If pneumatic hammers are used for removal of concrete, they should be of medium to light weight and operated very carefully so that no fine cracks are caused in the exposed sound concrete due to hammering operations.

6.3. Case II—When Removal of Concrete in Depth is not Required

Those surfaces or areas which are sound, and do not require concrete removal in depth, must be thoroughly cleaned to remove oil, dirt, asphalt, mortar droppings, weak laitance etc. At joints, the sealing compound should be completely removed to expose clean sound concrete. For dust, dirt, debris, mortar droppings and asphalt patches, scrubbing with iron brushes or sand blasting should be adopted. Oil can be removed by a detergent wash, and animal fat by scrubbing with a solution of sodium hydroxide, taking due precautions in the handling of sodium hydroxide in view of its corrosiveness. Light chiselling (upto a depth of 1 mm) is beneficial even where extraneous matter are not present at the surface. Chiselling may however, not be done where the surface has already been adequately sand blasted. If neither chiselling nor sand blasting can be adopted, the cleaned surface may be treated with dilute hydrochloric acid @ 4 kg per 10 sq. m. in two applications. Sand blasting and chiselling are, however, to be preferred over acid treatment. To ensure uniform coverage, acid should be spread by iron brushes or brooms. It is allowed to remain in contact with concrete for about 5 minutes. After foaming action has ceased, the surface may be finally flushed with water, together with vigorous scrubbing with an iron broom or brush, to remove all dislodged particles and other extraneous matter till all traces of acid as tested by litmus paper are removed. Flushing operation should be carried out without delay since the product of reaction forms a gel, which would prevent bond instead of promoting it if left long on the concrete.

6.4. Case III—When Cracks are to be Repaired

For repair of fine cracks or cracks with no edge spalling, no surface preparation beyond cleaning the strip of concrete on either side of the crack is needed. In case of wider, spalled cracks, all foreign matter including joint sealing compound used to seal them should be fully removed from, in and around the cracks with the help of rakers and chisels. Any unsound concrete around the crack should also be chiselled out, and a trapezodial notch formed at the top along the crack either by chiselling or using a joint cutting machine. The prepared notch should be at least 3-4 cm deep and 4-5 cm wide. For better interlock, the bottom width of the groove should be kept slightly more than the width at the top. The mode of formation of the groove is illustrated in Fig. 2.

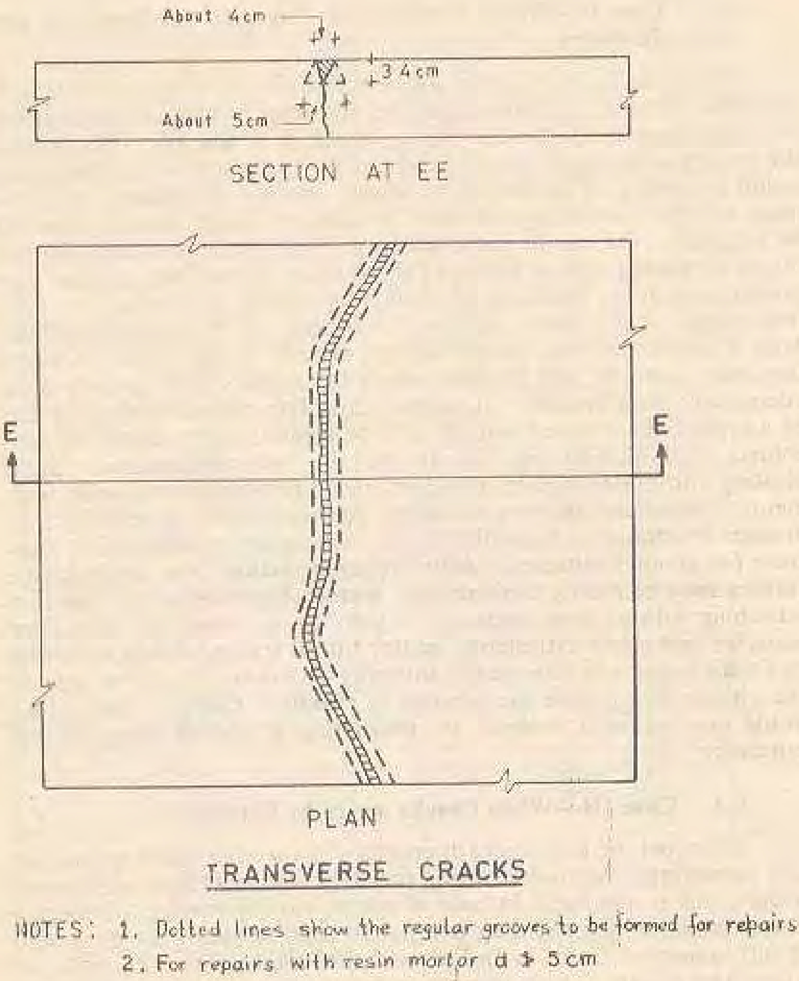


Fig. 2. Preparation of surface groove for resin repair of cracks

6.5. Final Cleaning Before the Repair

The prepared surface, recess or groove should be blasted with compressed air to clean it thoroughly and made dry before the resin application. When compressed air is used, it should be ensured that the compressor has an oil trap to guard against the possibility of the surface getting contaminated with oil.

6.6. Application of Tack Coat

6.6.1. All resin repairs commence with the application of a tack coat on the prepared concrete surface, using the same resin formulation which is selected for use in the resin mortar/resin concrete for the repairs. The tack coat should be applied with a hair brush, though brooms or spraying equipment can also be used. It should be ensured that the concrete surface is fully wetted. If one coat is not found enough for the purpose, e.g. when concrete is porous or made of absorptive material, a second coat should be given. The second coat should be applied while the first coat is still tacky.

6.6.2. Normally for one coat of tack coat for horizontal surface, as in the case of pavements, one coat of application is about 1.6 mm thick and the approximate amount required is 3.2 kg/10m² or 2.9 kg/10m² for epoxy and polyester resin formulations respectively.

6.6.3. The material to be laid over the tack coat (whether it be resin mortar or concrete, cement concrete, or simply a layer of sprinkled sand) should be placed in position while the tack coat still retains its tackiness. In case the tackiness is lost, another tack coat should be given after roughening the surface of the earlier tack coat to ensure good bonding.

7. REPAIR TECHNIQUES

7.1. Patching of Potholes, Spalled Areas, Pop-outs, etc.

7.1.1. The affected portions should be prepared in accordance with the procedure described in para 6.2. If the patch is adjacent to a joint, it should be ensured with the help of formwork that the sides of the joint do not get bonded while patching, and the required width and depth of the joint groove are maintained. This can be done by introducing wooden or metal strips of appropriate size, after covering them with alkathene or mobil oil for easy removal, and securing them firmly in position so that they do not get disturbed during repairs.

7.1.2. The tack coat should be applied to the prepared surface as per para 6.6. It should be ensured that the bottom as well as sides of the prepared groove are fully coated with resin formulation. Special care should be paid to edges and corners which are more prone to be left uncoated. For small sized work, a 20 mm hair brush may be used.

7.1.3. Before the tack coat loses its tackiness, resin-sand mortar or concrete, depending on the depth of the patch, should be placed in the grooved recess with the help of a trowel. For patches thicker than 20 mm, the sand should be combined with a coarse aggregate having maximum size not greater than one-third the thickness of the patch. If the patch is deeper than 5 cm, it should be built up in two or more layers to reduce heat build-up and subsequent thermal contraction. Full compaction should be ensured by rodding. The surface may be finished with a float or trowel. A light layer of sand should be spread over the finished patch.

7.1.4. To expedite patching operations, if necessary the area to be patched could be heated as indicated in para 5.2. Tack coat should be applied when the surface temperature has dropped to about 40° C. After application, the resin patch should be kept at a temperature of 30°-40° C to accelerate curing. For this purpose, infra-red lamps, electric heaters, hot air blowers, electric bulbs of 1000 watt capacity, or any other suitable arrangement may be used.

7.2. **Skid and Wear Resistant Layer**

7.2.1. The treatment may be in two or more layers depending on the severity of the problem. A minimum of two layers is considered essential, as under heavy traffic or severe climatic conditions, a single layer treatment may not last long.

7.2.2. For the first layer of surface treatment, immediately after tack coat has been applied, fine aggregate conforming to para 2.2 should be spread uniformly over the resin wet surface somewhat in excess of the quantity required to cover it. After the resin has hardened, the excess fine aggregates should be brushed off and saved for reuse. The quantity of fine aggregates needed for a single layer application is of the order of 16-17 kg. per 100 m² of the surface. For each subsequent layer, the process is repeated on the earlier cleaned layer.

7.2.3. Treatment may conveniently be applied to one lane width at a time in strips of suitable length, giving 2-3 cm overlap between successive strips. Workmen should not be allowed to walk over the prepared surface during the application of the treatment, so as to keep it clean for ensuring good bond. Suitable wooden bridges could be provided for the workmen to operate from.

7.2.4. Care should be taken to ensure that no resin gets into the joints. If there are any cracks in the concrete surface, they should be repaired in accordance with the procedure described in para 7.3, before giving surface treatment.

7.3. **Crack Repairs**

7.3.1. Before attempting to treat cracks with resin, the cause of such cracks should be ascertained. If the cracks are due to gradual subsidence of the subgrade or sub-base course, it should be checked whether subsidense is likely to continue or not. This can be done by proof rolling with a heavy roller or comparative load-deflection tests. If further settlement appears likely, repair would only serve as a temporary expedient and permanent rectification would require dismantaling the affected portions, compacting the foundation adequately including redoing it with suitable materials wherever necessary and laying new concrete slab on the properly constructed foundation.

7.3.2. In case of settled areas, the surface profile should first be corrected by pressure grouting, alone or in conjunction with mechanical lifting of the slabs. Mechanical lifting in conjunction with pressure grouting can be used more conveniently as the surface level can be better adjusted, and much smaller pressure is required for grouting in this case. Where facilities for such operation are not available, the depressed area might be treated as per para 7.1 or 7.5., depending on the amount of patching required to be done after the cracks are repaired.

7.3.3. Fine shrinkage cracks (less than 0.2 mm in width) may not need any treatment. Other cracks should be cleaned and prepared for repair vide procedure given in para 6.4. These cracks may then be filled by injecting them with suitable resin formulation. If the exposed crack faces cannot be reached, crack repair may be done by pressure injection, using a low viscosity resin. Proper crack repair by injection, however, is practicable only if the cracks are thoroughly clean.

7.3.4. For pressure injection or filling liquid resin into a crack, holes are drilled into the crack at regular intervals. These holes should be about 20 mm dia. and extend about 12 to 25 mm below the surface of the slab or the prepared groove as the case may be. Into these holes, pipe nipples or tyre valves are bonded with resin formulation. In case of cracks less than 1 mm wide for which no groove has been formed, a rapid setting resin formulation may be applied to the face of the crack to bridge it. For grooved cracks, bridging may be done by filling the groove fully or partly with resin sand mortar as is done in case of patching of spalled areas etc. To grout the crack, synthetic resin formulation is then forced into the nipple or valve with air pressure from a standard paint pressure pot through hoses. The formulation may be placed in a disposable container within the paint pot. Caulking gun or hydraulic pump can also be used for the purpose. Injection proceeds from one end of the crack to the other through adjacent nipples or valves. Care must be taken to inject the formulation at such a rate that the pressure required to inject does not exceed the pressure which the surface seal can tolerate. During the injection operation, it is difficult to be sure that the crack is completely filled. One way of checking this is to continue injection through one nipple or valve until the formulation starts coming out of the next one. At this point, the first nipple or valve must be capped off and injection started on the nipple or valve which has just begun to show the formulation overflow. The spacing of the nipples or valves may be decided by trial. After the crack is fully injected, the pipe nipples or tyre valves should be removed, if necessary by cutting and grinding flush with surface. If the crack groove has been only partly filled with the resin mortar in the first instance, it should be filled flush with the surface.

7.4. **Resin Mortar Overlays**

7.4.1. Such overlays may be necessitated under extremely heavy traffic conditions involving iron-tyred or studded tyred traffic. They may also be provided in case of strengthening of existing bridge deck where conventional measure of strengthening with plain or reinforced cement concrete which would involve undue increase in the self weight of the structure.

7.4.2. In these overlays, joints should be matched with the existing joints, both in location and type, and meticulous care taken to avoid bridging of the joint groove due to flow of resin mortar. Suitable inserts of wood or other material may be properly fixed over the existing joints for this purpose. Any crack in the existing pavement should be appropriately repaired before overlaying.

7.4.3. Fixing of formwork at outer edges of the pavement would present no difficulty, and can be done as in the case of normal concrete pavement. For intermediate lanes, wooden planks retained in position by wooden blocks fixed to the existing pavement at regular intervals by resin formulation can be used. Cube blocks of 5 cm size at 50-70 cm interval may be adequate for this purpose.

7.4.4. The procedure for over laying is basically the same as in the case of patch repairs (para 7.1). The tack coat should be applied as per para 6.6. Where reinforcing bars are exposed, they should also be thoroughly cleaned and given tack coat before overlaying with resin mortar or concrete. In view of large areas involved, greater attention is needed to ensure proper surface finish. Somewhat richer mixes vis-a-vis those for patch repairs with better workability are helpful in achieving better surface finish, and easier compaction by trowelling. In case a rough texture surface is required, it is possible to give a broom finish to the resin mortar overlay.

7.5. **Resin-bonded Cement Concrete Overlay/Resurfacing**

7.5.1. Cement concrete overlay resurfacing can be bonded to the existing cement concrete pavement by applying a coat of epoxy resin formulation, preferably of flexible type (e.g. E-2 of Appendix 3) on the prepared clean, dry surface of the latter. Only epoxy resin formulation should be used for the purpose.

7.5.2. The existing surface should be cleaned and treated vide procedure in para 6. The potholes, popouts, cracks etc., on the existing surface should be treated in accordance with paras 7.1 and 7.3. Mild steel shear pegs, if required, may be provided vide procedure in para 7.7. A mild steel bar mesh, extending 50 cm on either side of the crack should be embedded at mid-depth in the concrete overlay. Joints in the overlay should be matched with those in the existing pavement both in type and location.

7.5.3. Formwork may be held in position by suitable wooden blocks bonded to the existing concrete surface, as in case of resin mortar overlay.

7.5.4. The bond coat of resin formulation should be applied to the prepared surface as indicated in para 6.6 for tack coat. While applying this coat, accidental flow of resin formulation into the joints should be carefully guarded against. Extra care should be taken to ensure that all edges and corners of the concrete slabs are fully coated with the resin formulation. This is particularly important as these regions are more susceptible to warping as well as initial differential drying shrinkage stresses, and failure of bond in bonded concrete overlay normally starts from these regions. At low temperature, and with very rough surface of existing concrete, thicker coats may be adopted. The fresh concrete should be placed and compacted while the bond coat on the existing surface is still tacky.

7.5.5. Minimum thickness of such overlays/resurfacing should be 75 mm.

7.6. Curing and Opening to Traffic

The resin application should be well cured giving adequate time before opening to traffic. For normal curing resins, a minimum curing period of 4 hours in summer and 6 hours in winter would generally be adequate. In the case of cold weather or slow curing resin formulations, if the repaired sections cannot be closed to traffic for the normal curing period required for these conditions, curing period can be reduced by curing at elevated temperature through application of artificial heat as indicated in paras 5.2 and 7.1.4.

In the case of resin bonded cement concrete overlays and resurfacings, wet hessian curing should be commenced as early as possible after laying the cement concrete. Curing by ponding with water should be adopted a day after concreting, and continued upto 28 days age. As resin formulations for bonding new concrete to old are slow-setting (see para 2.1.2, item 3), any lapse in curing, especially in the earlier stages, may loosen the contact between the two concretes through warping of the upper layer. If the resin formulation sets in this condition, effective bond cannot be obtained between the two layers. In case of time constraint, rapid hardening cement may be used in the overlay concrete, for which 7-day curing would be adequate.

In either case, after curing is over, the pavement surface should be cleaned to remove all foreign matter, and the joints properly sealed before the pavement is opened to traffic.

7.7. Fixing Mild Steel Shear Pegs in Existing Concrete Pavement before Overlaying/Resurfacing

Shear pegs are required to be used along the edges of concrete pavement for preventing separation of the overlay/resurfacing from the existing pavements. They can be effectively bonded to the existing pavements with epoxy or polyester resin. They consist of 20-25 mm dia mild steel bar, plain or threaded, and with a mild steel plate 10 cm × 10 cm × 10 mm welded or screwed at the top.

The mild steel bars are fixed with resin mix in holes drilled in the existing pavement. The holes may be drilled with pneumatic rock driller. The diameter of the holes should be 15-20 mm more than that of shear peg bar. The depth of the holes need not be more than 15-20 cm, as a 20 mm dia. plain bar shear peg with an embedment length of 15 cm can take a minimum pull load of 650 kg, and a 25 mm dia. plain bar shear peg of 900 kg. However, while drilling the hole, at least 5 cm concrete cover should be left at the bottom, in order to prevent splitting up at the bottom.

Resin sand mortar is introduced in the thoroughly cleaned hole in an amount just sufficient to fill the gap between the shear peg and the hole. The shear peg is given a coat of resin formulation upto the depth of embedment before insertion. The shear peg may be kept stable in its required position by supporting its top plate from below with blocks or by other means.

8. CONSTRUCTION PLANNING FOR RESIN REPAIR OF CONCRETE PAVEMENTS

8.1. A variety of factors have to be considered, in addition to visual condition survey, for ascertaining the type and extent of repairs required. Some cases may need detailed field investigation including load tests, especially when settlement of the pavement is evolved.

8.2. The climatic conditions and working constraints under which the repairs have to be carried out should be kept in view for deciding the appropriate materials (especially resin formulation), mix proportions, special measures needed (e.g. temperature conditioning of the prepared surface and repair materials, curing at elevated temperature etc.), and manpower and equipment requirements. If the workers are not already trained in resin repair techniques, specific provision should be made for such training in view of specialised nature of the work.

8.3. A broad outline of resin repair system for concrete pavements, which can provide general guidance in this respect, is given in Fig. 3. This sequence of operations, considered in conjunction with the various climatic and operational constraints, as well as the type and extent of repairs involved, should be examined to assess and clear the likely bottlenecks in execution.

8.4. Manpower and equipment requirements should be planned out to take care of these various bottlenecks to the maximum extent possible. For example, where time constraint is

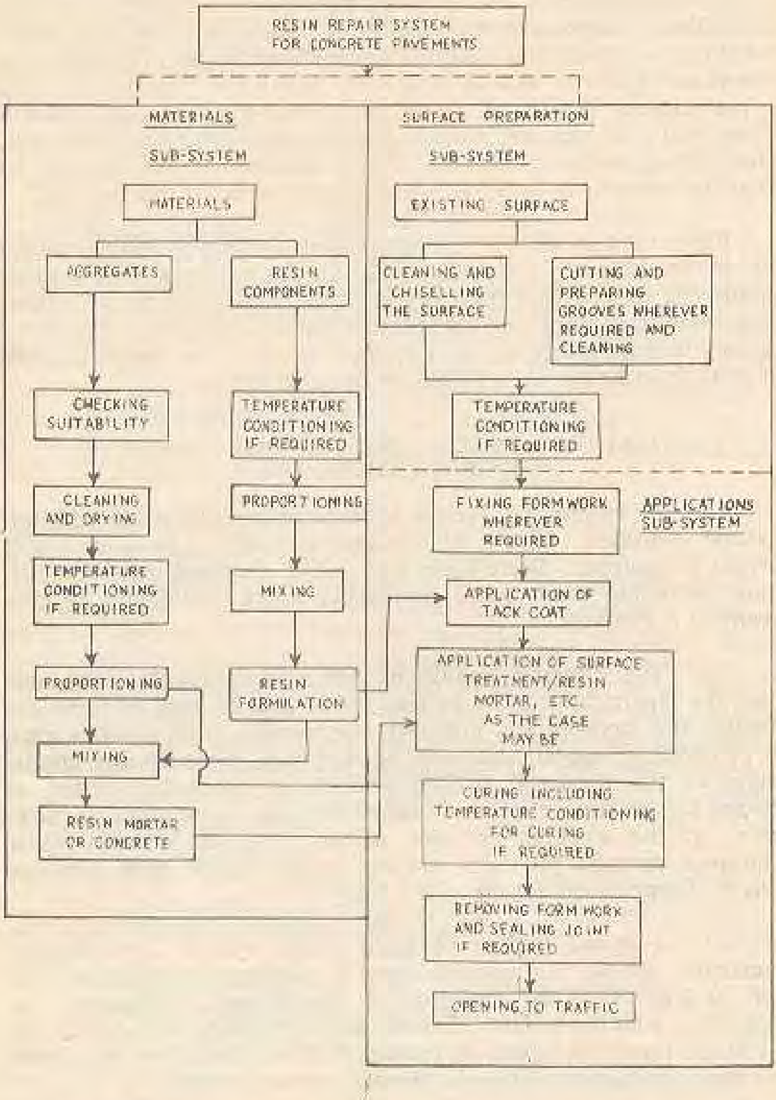


Fig. 3. Broad outline of resin repair system for concrete pavements

severe, surface preparation involving cutting and forming of grooves in the concrete would be a major bottleneck, unless mechanical means are employed for the purpose. Fixing of appropriate formwork in case of edge or corner spalling can be another bottleneck in certain cases. In cold climates, heating of the pavement and materials, and subsequent heating of repaired section for curing may present still another bottleneck. Adequate provision should be made for standby equipment units, as well as skilled carpenters (for preparing and fixing formwork for edges or corner spall repairs), masons (for proper surface finish), and if possible a stone-dresser (for final finishing of grooves for repairs).

9. QUALITY CONTROL OF RESIN REPAIR WORK

9.1. Strict quality control is essential through employment of trained workmen and adequate supervision staff for the specialised nature of resin repair work. The quality of basic materials as well as the finished product should be constantly checked to ensure good quality work.

9.2. Checking the Quality of Finished Work

9.2.1. **Field bond strength:** As the effectiveness of the repair depends on the bond developed with the old concrete, it is recommended that tests should be made in the field or on samples recovered from the repaired portions to ensure adequate bond strength. The type of tests and minimum recommended bond strength values are given below:

Type of Repair	Type of Test	Min. Bond Strength Value
(i) Resin bonded cement concrete (cement concrete to cement concrete bond with epoxy resin)	(a) Tensile bond strength (b) Shear bond strength	$7.5\ kg/cm^2$ at 28 days $15\ kg/cm^2$ at 28 days
(ii) Resin mortar repairs on cement concrete (both for epoxy and polyester resin repairs)	(a) Tensile bond strength (b) Shear bond strength	$7.5\ kg/cm^2$ at 7 days $15\ kg/cm^2$ at 7 days
(iii) Fixing shear peg with resin mortar	(a) Pull out shear bond strength	Pull out load at 2 days $= 1.2 \times$ design pull out load for shear peg

The test procedures for these tests are given in *Appendix 4*.

9.3. **Resin Content in Hardened Resin Sand Mortar**

9.3.1. It may sometimes be required to check the resin content in hardened resin-sand mortar, if repairs have not been found to be satisfactory. This can be done expeditiously but approximately determining loss on ignition at 1000°C. The test procedure is given in *Appendix 5*.

Appendix-I

SUGGESTED TEST PROCEDURES FOR DETERMINING THE PROPERTIES OF RESINS AND RESIN MORTARS

I. Pot Life of Resin Formulation

(a) Prepare 500 gm of resin formulation by thoroughly mixing the resin and hardener/accelerator/catalyst components in proposed portions in a 1 kg capacity hemispherical porcelain bowl by means of a spatula or any agitating device.

(b) With a clean, dry, 25 mm size painter's brush, apply the resin formulation on a clean dry surface such as cement concrete over 15-20 cm length, starting immediately after mixing the formulation, and repeating the operation every five minutes.

(c) When it becomes just difficult to spread the resin properly with the brush, the time is noted. The time elapsed since completion of mixing of resin formulation is taken as its pot life.

II. Compressive Strength of Resin Mortar

(a) Prepare 3 nos cubes of 5 cm size for each proposed mix of resin sand mortar, compacting in the moulds by means of 1 cm square mild steel rod of 20 cm length in two equal layers, and finishing by removing the excess with a steel trowel.

(b) Cure in air at 30°± 2°C till the time of test. The samples may be demoulded 3-24 hours after casting depending upon the resin formulation, being fast setting or slow setting.

(c) Test the cubes in a compression testing machine at a rate of loading of 140 kg/cm² per minute, noting the maximum load taken by the cubes, and calculate compressive strength from the average of three cubes for each mix.

III. Moisture Susceptibility

(a) Prepare for each resin mortar mix six 5 cm cubes as for compressive strength test.

(b) After 48 hours of casting, 3 cubes are immersed in water at 30°± 2°C, the remaining 3 cubes being cured in air at the same temperature for a further period of 7 days.

(c) Obtain average compressive strength for water cured and air cured samples separately and determine the per cent loss for water immersed samples vis-a-vis air cured reference samples.

(d) This per cent loss in compressive strength is taken as an index of moisture susceptibility of the resin mix.

IV. Bond Strength (of Resin Mortar-Cement Concrete Composites)

(a) Prepare 3 cement concrete blocks 10 cm × 10 cm × 7.5 cm with M-350 cement concrete, by cutting from 10 cm × 10 cm × 50 cm beam or casting to size.

(b) In case of samples cast to size, prepare the surface to be bonded by 1 : 1 dilute. HCL acid treatment, in two applications finally washing profusely with water and fully drying them in air. In case of samples cut from beams, use the saw-cut clean, dry face for bonding.

(c) Apply resin formulation to the prepared clean dry surface. When the formulation is still tacky apply 2.5 cm top layer of proposed resin—sand mix, compacting in 10 cm mould by means of 1 cm square mild steel rod of 10 cm length and finishing by removing the excess with a steel trowel.

(d) Cure in air at 30° ± 2°C for 2 days and determine the bond strength through direct shear at the line of interface, at the rate of loading of 140 kg/cm² per minute, noting the maximum load taken by the composites and calculate shear strength from the average of three composites for each mix.

V. Shrinkage of Resin Mortar

(a) Prepare 3 mortar bars of 2.5 cm × 2.5 cm × 28.5 cm size for each proposed mix, compacting in the moulds by means of 1 cm square mild steel rod of 20 cm length in one layer, and finishing by removing the excess with a steel trowel. Cure in air at 30° ± 2°C.

(b) Insert one pin at both ends of each resin mortar bar.

(c) Determine the distance between two pin heads initially by means of a travelling microscope.

(d) Repeat the process of measurement when the mortar has set (after 2 days).

(e) Calculate shrinkage value from the average difference between two observations for three bars for each mix.

VI. Coefficient of Thermal Expansion of Resin Mortar

(a) Prepare 3 mortar bars of 2.5 cm × 2.5 cm × 28.5 cm as for shrinkage test.

(b) Cure for 2 days in air at 30° ± 2°C.

(c) Use standard thermal expansion apparatus with telescope-mirror attachment for measuring the expansion of mortar bars.

(d) Take initial reading of the position of top of the bar through the telescopic mirror at room temperature and start heating the specimen by circulating steam in the apparatus. When there is no further increase in temperature, take the final reading and calculate the difference between the two readings.

(e) Calculate coefficient of thermal expansion from the average of three mortar bars for each mix.

VII. CRRI Accelerated Weathering Test for Durability of Resin Mortar-Cement Concrete Composites

(a) Select appropriate weathering cycle/cycles for the test according to the climatic conditions at the proposed site of use of resin under reference, from the following three different cycles:

Type-I : Extreme hot climate—Alternate heating and cooling cycle: Heating in air at 80°C for 6 hours and cooling in air at 30°± 3°C for 18 hours.

Type-II : Extreme cold climate-Alternate freezing and thawing cycle: Freezing at 12° ± 2° C for 6 hours and thawing in air at 30°± 3°C for 18 hours.

Type-III: Alternating extreme hot and cold conditions-Alternating heating and cooling cum freezing and thawing cycle: Freezing at 12° ± 2°C for 18 hours, follwed by thawing in air for ½ hour and in water for ½ hour, heating in air at 80°C for 4 hours, cooling in air at 30° ± 3°C for ½ hour and immersing in water for ½ hour. This cycle is the severest weathering cycle of the three.

(b) For each type of weathering cycle, prepare one set of 3 resin mortar-cement concrete composite specimens as in case of bond strength test (item IV above) and 3 resin mortar cube specimens as for compressive strength test (item II above). Also prepare one set of six control specimens (those not be subjected to weathering cycles) as above.

(c) Cure the weathering test specimens in air for 24 hours at 30°± 2°C, and subject them to 30 weathering cycles.

(d) To study the effect of interfacial bond between resin mortar and cement concrete, carefully examine the test specimens after each cycle for any bond cracking at the interface and when such cracking is noticed, record the number of cycles required to cause cracking. Throughout this period, the control specimens are cured in air at a temperature of 30°± 2°C.

(e) After the completion of 30 cycles, test the weathered specimens as well as control specimens for bond and compressive strengths. Calculate these strenghs for weathering test specimens as a percentage of those for the control specimens.

Appendix 2

TYPICAL VALUES OF DIFFERENT PROPERTIES OF RESIN FORMULATIONS AND MORTARS

Resin Formulations

Resin Formulation Property	*Epoxy Resin*	*Polyester Resin*
Coefficient of thermal expansion (10^{-6}/cm/°C)	23-25	20-35
Viscosity (centipoise at 27°C)	4000-10000	5000-10000
Linear shrinkage, max. (%)	0.1	0.1
Specific gravity,		
min.	1.05	—
max.	1.20	0.9—1.0
Pot life (Minutes) (varies with accelerator used)		
25°C	90	80
30°C	60	60
35°C	45	40
Storage life	At least 12 months	At least 12 months
Moisture Susceptibility	Slightly susceptible	Susceptible

Resin Mortars	*Epoxy Resin-Sand Mortars*	*Polyester Resin-Sand Mortars*
Compressive Strength of 1:3 to 1:6 mortars with both fine and medium sand (kg/cm²)	350-1000 (at 2 days)	650-800 (at 1 day)
Tensile Strength of 1:3 to 1:4 mortars with fine sand (kg/cm²)	80-100 (at 2 days)	100-120 (at 2 days)
Flexural Strength of 1:3 to 1:4 mortars with fine sand (kg/cm²)	400-500 (at 7 days)	350-450 (at 7 days)
Bond strength of 1:3 to 1:6 mortars with both fine and medium sand (kg/cm²)	25-45 (at 2 days)	25-45 (at 2 days)

Appendix 5

TYPICAL RESIN FORMULATIONS AND THEIR SUITABILITY FOR DIFFERENT USES

(A)	**Typical Epoxy Resin Formulations Components**	**Parts (by wt.)**
E-1	Epoxy resin (Diphenylol propane epichlorhydrin)	100
	Hardener-I (Polysulphide polymer)	53
	Hardener-II (Tertiary amine)	4
E-2	Epoxy resin (Diphenylol-propane epichlorhydrin)	100
	Hardener-III (Polyamide)	20
	Hardener-IV (Amine adduct)	20
	Hardener-V (Amine adduct-fast curing)	20
E-3	Epoxy resin (Diphenylol-propane epichlorhydrin)	100
	Hardener-III (Polyamide)	45
	Hardener-II (Tertiary amine)	5
E-4	Epoxy resin with reactive diluents (Diphenylol propane-epichlor hydrin with reactive diluent)	100
	Hardener-IV (Amine adduct)	45
	Hardener-II (Tertiary amine)	5
E-5	Epoxy resin (Diphenylol-propane epichlorhydrin)	100
	Dibutyl phthalate	7
	Hardener-IV (Amine adduct)	44.6
	Hardener-V (Amine adduct-fast curing)	22.3
E-6	Epoxy resin (Diphenylol-propane epichlorhydrin)	100
	Hardener-VI (Medium fast-amine hardener)	50
E-7	Epoxy resin (Diphenylol-propane epichlorhydrin)	100
	Hardener-VII (Slow-amine hardener)	50
E-8	Epoxy resin with fine silicious filler (Diphenylol-propane epichlorhydrin with fine silicious filler)	100
	Hardener-VII (Medium fast-amine hardener)	50
E-9	Epoxy resin with fine silicous filler (Diphenylol-propane epichlorhydrin with fine silicious filler)	100
	Hardener-VII (Slow-amine hardener).	50

(B)	**Typical Polyester Resin Formulation Components**	**Proportion**
P-1	Polyester resin (solution of unsaturated polyester and monomer styrene)	100 gm
	Catalyst (Peroxide)	2.5 ml
	Accelerator (Cobalt Naphthenate)	0.5 ml

(C) Suitability of Different Typical Resin Formulations for Different Uses-Preliminary Resin Selection Chart

Type of Use	Suitable Resin Formulation
1. Bonding new cement concrete to old (Resin-bonded cement concrete overlays/resurfacings/ patch repairs)	E-2
2. Resin mortar/resin concrete repairs (Patching of potholes, spalled areas, popouts etc., resin mortar overlays)	*(a) Fast Curing: E-3, E-4, E-6, E-8, P-1** *(b) Medium Curing: E-1, E-5, E-7, E-9 +(c) Slow Curing: E-2
3. Skid and wear resistant layers	Same as under item 2
4. Crack repairs (by injection of resin formulation)	*(a) Medium Curing: E-6++ *(b) Slow Curing: E-7++

* Only when the existing surface is completely dry at the time of repair.

** Only in areas of dry climate and low water-table when the repairs are not likely to be subjected/exposed to moisture effects.

\+ For use under conditions where (a) and (b) are not suitable.

++ Low viscosity resins.

Appendix-4

TEST PROCEDURES FOR CHECKING THE ADEQUACY OF BOND BETWEEN OLD CONCRETE AND OVERLAID MATERIAL

I. Tensile Bond Strength Test

1. Field Test Procedure

(a) Using a core cutting drill of 100 mm dia. make a cut at the selected test location through the overlaid concrete or resin mortar and the bonding resin formulation, so that the cut slightly extends into the old concrete, producing a cored island on the surface.

(b) Take a set of standard pipe cap and pipe plug so that the outer diameter of the pipe cap is slightly bigger than 100 mm and the pipe plug can be screwed into the pipe cap. (Normally pipe cap for 75 mm inner diameter pipe and pipe plug for 87 mm inner diameter pipe should serve this purpose). The closed end of the pipe cap should be machined smooth on the outside, and its cylindrical surface shoulder-cut to provide 100 mm dia. surface. The top of the pipe plug should be provided with a suitable steel hook or straight bar for applying the tensile test load.

(c) Fix the machine-smoothed pipe cap to the surface of the cored island by epoxy resin bonding.

(d) Screw the pipe plug into the pipe cap bonded to the cored island.

(e) For applying the test load, any suitable arrangement such as a mechanical swivel head, hydraulic jack or Gifford Udall prestressing jack may be used, in conjunction with appropriate connecting and load measuring arrangement. Fig. 4 illustrates some typical arrangements.

(f) Applying test load of 1.6 tonne gradually. If the cored island does not fail at the bonded interface or elsewhere upto this load, the bond developed can be considered as adequate.

If the failure occurs at the bonded interface before the test load of 1.6 tonne, the extent of bond strength developed is not adequate. If failure occurs elsewhere in the cored island, the test should be considered inconclusive as regards interfacial bond, and be repeated at another location.

2. Laboratory Test Procedure

(a) Using a core cutting drill, a 100 mm dia. core should be recovered upto full depth from the test location.

(b) Prepare the test piece by making saw cuts at distance of 50 mm on either side of the bonded interface resulting in a

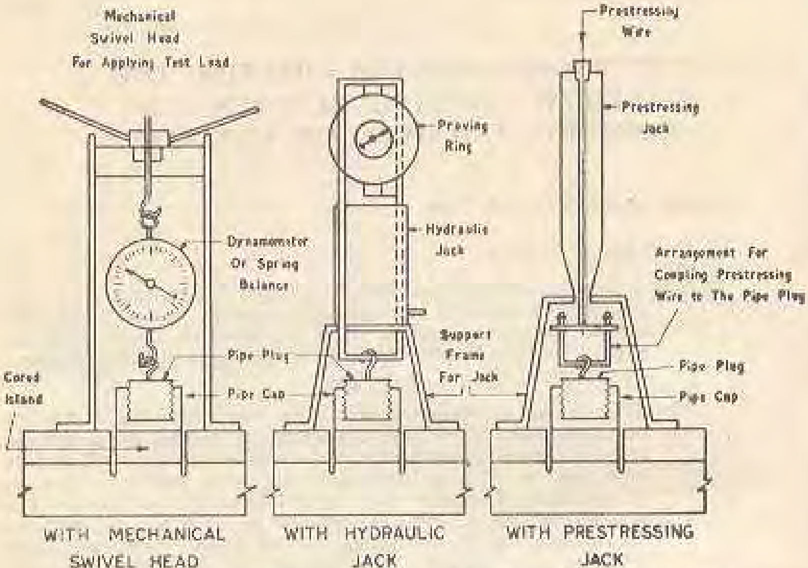


Fig. 4. Some typical arrangement for insitu tensile bond strength test in the field

100 mm long cylinder. In case of thin resin mortar treatments, only one cut need be made in the old concrete, at a distance of 50 mm from the concrete-resin interface.

(c) Two sets of pipe caps and pipe plugs, with mild steel bars welded to pipe plugs for application of test load, shall be prepared as at (b) under the Field Test Procedure. Bond the two prepared pipe caps to either face of the test piece with resin formulation.

(d) Screw the pipe plugs into the pipe caps at the time of test. Perform the test by applying the test load through the bars welded to the pipe plugs.

(e) The test should be carried to failure, and the bond strength so developed calculated. The test results may be interpreted in the same way as for the field test.

II. Shear Bond Strength Test

(a) Using a core cutting drill recover a 100 mm dia. core upto full depth from the test location.

(b) Prepare a 100 mm long test piece by making saw cuts in the old concrete and the new overlaid material, at distances of 75 mm and 25 mm respectively from the bonded interface.

(c) Test the specimen in shear bond by shearing the 25 mm end slice from the cylindrical test piece. The test piece should be tightly held in suitable clamps on either side of the bonded interface, to ensure uniform application of load over the test specimen (Fig. 5). Alternatively, the test piece can be cast in concrete cubes to facilitate clamping for the test.

(d) If the test specimen does not fail in shear bond upto a load of 1.6 tonne, the bond developed shall be considered as adequate. The shear bond strength developed may be obtained by loading to failure, and dividing the total failure load by the cross-section area of the cylinder.

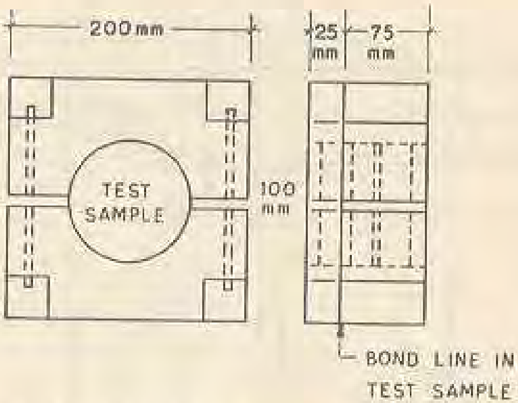


Fig. 5. Arrangement for shear bond test on core samples recovered from field

III. Pull-out Load Test for Shear Pegs

(a) Adopt a set up similar to the one shown in Fig. 6 for conducting pull out load test for shear pegs.

(b) Apply a total load of 600 kg in case of 20 mm dia. shear pegs, and 800 kg in case of 25 mm dia. one, in four equal increments, deserving for any slippage after each load increment.

(c) If no slippage occurs upto full test load, the shear peg should be regarded as adequately bonded.

(d) In case of slippage at a load lower than the pull test load, the load increment just before the one at which slippage occurred will be regarded as the load carrying capacity of the shear peg.

(e) In all cases of inadequate load carrying capacity, the shear peg should be removed, and fixed afresh after removing the resin mortar from the hole in the existing pavement by pneumatic rock driller.

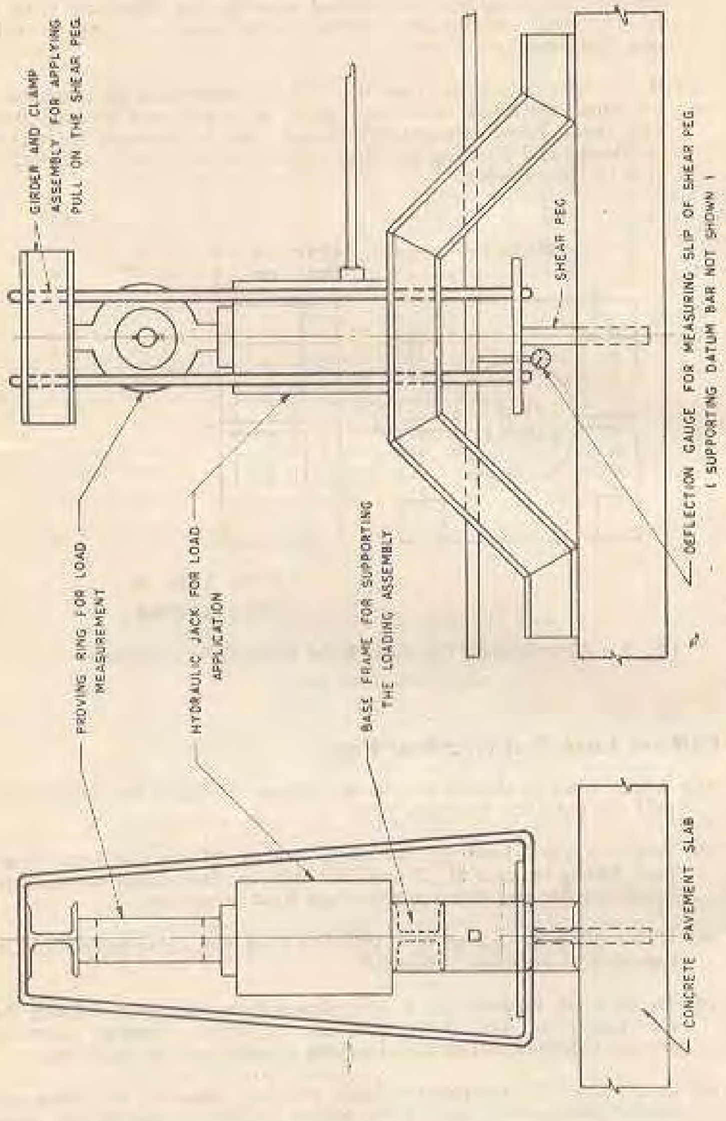


Fig. 6. Typical set-up for pull out load test on a shear peg

Appendix 5

TEST PROCEDURE FOR APPROXIMATE DETERMINATION OF RESIN CONTENT IN HARDENED RESIN MORTAR

Obtain a representative sample of the hardened resin-sand mortar (Every precaution should be taken to ensure a truly representative sample).

Weigh about 25 gm of the sample in a clean porcelain dish.

Place the porcelain dish with the sample in an electric furnace with a range upto 1000°C for ignition. To ensure constant weight after ignition, keep the sample in the furnace at 1000°C for 1 hour minimum.

After ignition, tranfer the porcelain dish to a desiccator and allow it to cool to room temperature.

Weigh the dish with the ignited sample.

Calculate resin content of mortar proportions as follow :

Let W_1=Weight of dry porcelain dish

W_2=Weight of porcelain dish+resin sand mortar sample, before ignition

W_3=Weight of porcelain dish+sample, after ignition

hen

$$\text{Resin content, } x\% = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

$$\text{Sand/resin ratio, } S = \frac{100 - x}{100}$$

Therefore the mortar proportion will be 1 resin: S sand

ote : This method will hold good only for siliceous sand.