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Sprayed concrete has been the most popular technique for the repair opf concrete ever since it was first introduced some fifty years ago. It is also used, though much less frequently in new constr4uction where the placement of concrete by conventional means poses problems. The term encompasses both gunite, which is applied to sprayed concrete with a maximum aggregate size of 10 mm or less, and shotcrete where the maximum aggregate size exceeds 10 mm. It involves conveying under pressure mortar or concrete through a hose, thereby projecting the material at a high velocity onto a surface. The force of the jet striking the surface compacts the material and produces a dense, homogenous mass. A relatively dry mixture in used, and the material is capable of supporting itself without sagging even when applied overhead or on a vertical surface.

Compared to concrete which is poured in place, the use of sprayed concrete has certain advantages in that :

i) it can be placed at any angle.

ii) It can produce quite complicated shapes with formwork on one side only or with no formwork at all, as in the case of repairs to existing structures.

iii) The mortar or concrete, as placed, is always visible so that any defects can be readily removed.

iv) It can be applied to almost any thickness.

v) It makes possible the placement of concrete in confined locations.

vi) Because of the low water-cement ratio used, high strengths are possible.

IT has also been claimed that good compaction and high density are attained, but this is debatable and much will depend upon the conditions and location of placement. In addition, there are also some specific disadvantages. For example, precise control over the water incorporated in the mix is difficult. The flow of materials, too, can vary. And, finally, rebound from the surface involves wastage of materials as well as weak and porous areas in the structure. However, these problems can be mitigated to a considerable extent by maintaining the equipment in good condition and by employing trained and experienced operators.

The method most commonly used to apply sprayed concrete is the dry process. In this process, the cement and aggregates are mixed dry and then conveyed pneumatically at a relatively high velocity to a nozzle where water is added in the form of a fine spray. In the wet process introduced about ten years ago, all the ingredients, including the water, are thoroughly mixed and conveyed at a low velocity through the delivery hose. At the nozzle additional air is injected to break up the solid stream and to accelerate the particles onto the surface. The wet process ensures better control over the quantity of water added and provides for more thorough mixing of the ingredients. The rebound losses and wastage are also found to be less. On the other hand, longer hose lengths can be used with the dry process, thus extending the range over which work can be carried out.

Though ordinary Portland cement is commonly favored for sprayed concrete, there is no bar on the use of other types of cement. In fact, for ground stabilization works, tunnel linings and marine structures it is not unusual to use sulphate resisting cement for sprayed concrete abroad, whilst in India itself there are many examples where refractory concrete, based on calcium aluminates cements have been placed by the gunite process. The maximum size of aggregate ranges, typically from 5 to 10 mm, though a survey carried out in Britain by the Concrete Society cities cases where 25-mm and even 40-mm sizes have been used. Whilst the typical mix has an aggregate cement ratio of 3:1 or 3.5:1 leaner mixes of 6:1 are by no means not unknown. The water cement ratio is normally within the range of 0.35 to 0.60, which is somewhat lower than for comparable concrete mixes placed by conventional methods. American experience shows that for shotcrete cylinder strengths at 28 days are in the range of 300 kg.,/cm.sq. to 500 kg./cm.sq., though higher strengths in the region of 700 kg./cm.sq. have also been attained. The Concrete Society survey, referred to earlier, also confirms on the basis of drilled cores that high strengths are attainable with sprayed concrete but reports that the standard deviation may be twice or even thrice that which could be expected from standard cubes.However, depending upon the mix proportions, the drying shrinkage varies from 0.06 to 0.10 per cent. This is relatively high compared with conventional concrete so that there is a greater risk of shrinkage cracking. Closer joint spacing is, therefore, desirable with sprayed concrete.

Both laboratory tests and observations under field exposure indicate that the durability of sprayed concrete is quite good. This is, of course, subject to good bond with the surface to which it is applied. Careful preparation of the surface is, indeed, a prerequisite if the repair or new work is to remain effective for any length of time. In the first instance, all unsound material should be removed until there are no offsets which would cause an abrupt change in thickness of the repaired portion. No square shoulders should be left at the periphery, and all edges should be tapered. Similarly, loose rust and scale on reinforcement should also be removed. The surface can then be sand blasted, followed by wetting and damp drying. Though sprayed concrete has excellent bond with a properly prepared surface, except in the case of repairs of small thickness the use of reinforcement is recommended. The best reinforcement is a standard wire mesh with a minimum spacing of 50 mm both ways. Bars too can be used but their size should preferably not exceed 25 mm and particular care has to be taken during gunning to ensure proper encasement. Bars larger than 25 mm diameter and heavy concentrations of chicken wire mesh can cause problems through increased rebound.

Admixtures are, sometimes, incorporated in sprayed concrete mixes, particularly in underground applications, to accelerate the rate of placing and to provide early strength for immediate rock support. There are, however, problems associated with their use especially in the case of the dry process. Moreover, the long term effects of accelerators have yet to be fully evaluated, and they should be used with even greater restraint than in the case of conventionally placed concrete if they are not chloride-free. Retarders could be added during hot weather if more time is desired for finishing. Mineral admixtures, though helpful in increasing plasticity and reducing sagging tend to increase shrinkage and are a hazard to health. They should, there4fore, be used with considerable caution.

A recent development, which is of considerable interest, is the incorporation of fibers sprayed concrete to enhance performance. Steel, Glass, Nylon and Polypropylene are some of the fibers which have been tried, both experimentally and in actual production, with the use of Steel Fibers predominating. Fibers improve the flexural strength, toughness and ductility of sprayed concrete. They eliminate the need for a steel reinforcing mesh and give better bond with an old surface. In the case of Steel, the fibers are available in a range of lengths and diameters, the size generally preferred being 25 mm long with an aspect ratio from 50 to 100. The main problems with fibers are to ensure their uniform distribution and that there is an effective volume of them in the sprayed concrete, particularly since the proportion of steel fibers that rebound is generally greater than that of the aggregate. To overcome the problem, equipment manufacturers in Britain have developed special dispensers, by means of which the fibers may be mixed with the Cement and Sand prior to conveying or separately introduced at the Nozzle through an additional pipeline.

The impact of the sprayed concrete on a surface or with the reinforcement causes some cement paste and particles of aggregate to ricochet. The percentage of rebound depends upon several factors but all other conditions being the same, the wet process produces only a third of the rebound compared to the dry process. This is so partly because with the wet process the water content for a given mix will generally be higher, resulting in a more plastic deposit which has a lesser tendency to rebound. Apart from this, the amount of rebound will depend upon the air pressures, cement content, water content, maximum size and grading of aggregate, amount of reinforcement, thickness of layer, and the distance of the nozzle from the surface. Of these, the last factor is quite critical, and for any set of conditions there is an ideal distance at which the least rebound will be obtained. A deviation of just 25 cm either way from this ideal distance can increase the quality of rebound from a mere 10 per cent to as much as 25 per cent. Finally, much depends upon the position of the surface, rebound being least when the material is directed to a surface vertically downwards and a maximum in the case of overhead work. Rebound material, being much leaner and coarser than the original mix, should never be reworked back into the construction nor should it be salvaged and reused in later batches.

Testing for quality control poses some problems in the case of sprayed concrete. Of course, hollow areas and inadequate bond can be located by striking a hard hammer on the finished surface. But, when the concrete is to be produced to a performance specification, the determination of compressive strength is, by no means, straightforward. Cubes cast with the mix proportions adopted for the actual spraying will remain inadequately compacted if conventional procedures of making specimens are adopted. Nor is it practical to cast a cube specimen using the sprayed concrete process itself. To overcome this problem, it has been suggested that test panels, 30 cm square and 7.5 cm thick, are prepared by gunning on a plywood form which is positioned at the same angle as the surface under construction. Cores or cubes could then be drilled or sawn from these panels for the compressive strength test. The procedure is certainly a practical proposition will yield specimens which are fairly representative of the concrete in place.

Sprayed concrete is a specialized process and requires skilled operators. Prior training and experience, therefore, count in ensuring high quality work. It is a particularly useful method for repairing deteriorated concrete and it has been used primarily for this purpose in India. It must, however, be appreciated that it is amenable to use in new constructions as well. Curved and folded plate roofs, tunnel and canal linings, encasement of structural steel sections and pipes, and placing refractory concrete in chimney and furnace linings are all examples where it has an edge over conventional methods of placement. There are, however, some areas where more research would be desirable to instill confidence in the technique for use in structural concrete. The most important of these areas relate to the properties of the deposited concrete and as to how variability in quality can be reduced. Progress in these directions will certainly be viewed with interest.

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