reason for this is believed to be that the voids in the course are interlinked, so that if any water is retained within the course, which ideally it should not be, it is free to expand on freezing.

The experience in the United States has been essentially the same as in the United Kingdom. White (2) concludes that no problems have developed from freezing and thawing cycles, but that a future problem may develop where heavy buildup of rubber occurs.

Some engineers believe that freeze-thaw damage can be avoided by ensuring that the open course is laid on a surface in excellent condition. The need for a good surface is specified by FAA. The main east-west runway at Stapleton International Airport, Denver, was not overlaid before applying the PFC, and freeze-thaw damage has occurred where reflective cracking has come through.

Tire Wear

The airlines report there is no significant increase in tire wear due to operations at airports having PFCs.

Rubber Contamination and Removal

Experience with rubber buildup and removal vary within Australia, the United Kingdom, and the United States. It is not known whether this is caused by climatic conditions, course design specifications, or some unknown cause.

The British have never found it necessary to remove rubber from PFCs. Although rubber deposits in the touchdown zone build up during the warm months, they largely powder away during the winter. No studies have been specifically aimed at determining whether rubber deposits clog the voids; however, no reduction in the effectiveness of PFCs from this cause has been observed.

However, the Australians report that the main problem with porous surfaces is the buildup of rubber in the touchdown zones, although rubber buildup is not as fast on porous surfaces as on dense bituminous concrete. They have had no success in removing rubber by chemical means. In the one trial carried out at Sydney, the porous surface broke down because a chemical reaction weakened the bitumen bond. Rubber removal by the use of diamond saw blades was initially successful, but the area has since been recovered with rubber and some of the advantage of the nature of the PFC texture has been lost.

There has been concern in the United States as to whether the cleaning of PFCs is a problem. Although the survey would indicate that rubber buildup on PFCs is neither more nor less than on other surfaces, and many believe that less cleaning is required, the use of PFCs in the United States has been limited, and reliable data are still not available.

A study of the main east-west runway at Stapleton Airport may offer a solution to the removal of contaminants. In 1972, a method for prolonging the use of the runway for 3 or 4 years became necessary. A PFC was applied after a preparatory heater scarification of the surface. Several design mixes were discussed, and a mixture of 13-mm (0.5-in) aggregate with 7 percent asphalt concrete and 1.5 percent neoprene synthetic rubber was selected. The course performed well for 4 years without cleaning.

In early summer 1976, Stapleton Airport authorities contracted with a commercial firm to remove the rubber. This firm used a high-pressure water blast with a rotating bar, a technique that has been evaluated by the National Aeronautics and Space Administration (3).

The rubber on the runway was 3 to 6 mm (0.13 to 0.25 in) thick, which necessitated the use of a biodegradable chemical to soften it. Water pressure of 48.3 to 55.2 MPa (7000 to 8000 lbf/in^2) was applied. There is no evidence of harm to the runway from either the chemical or the high water pressure, and no harm was caused because the solid state of rubber protected the open course.

A second cleaning was completed in mid-October. The rotating bar was used with the water pressure reduced to 34.5 MPa (5000 lbf/in^2). It is estimated that 90 percent of the rubber was removed at the edge where the buildup was light and 85 percent was removed where the buildup was heavy. Where the bar was stationary, aggregate was removed at a pressure of 27.6 MPa (4000 lbf/in^2).

In the view of the airport authorities and the contractor, high-pressure water can be used successfully to clean a PFC. It appears necessary, however, to use an actuating bar, preferably a rotating bar that strikes from 360°. A stationary bar provides too much dwell time and will cause damage.

The removal of contaminants remains a problem to be further studied, but it is appropriate to consider the following. On the basis of the rubber deposits at Salt Lake City Airport, it might have been concluded that Stapleton Airport would have been less susceptible to reverted rubber because it has a larger size aggregate with a more open-textured surface. However, considering the difference in traffic use, it is difficult to make an absolute conclusion. Very little reverted rubber has been observed at Salt Lake City. Apparently, once the rubber starts to bridge across the projected aggregate particles, it flakes off rather than completing the bridge.

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Abridgment

Fibrous Concrete Construction at Reno and Las Vegas Airports

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Construction projects using fibrous concrete at Reno International Airport, Reno, Nevada, and McCarran International Airport, Las Vegas, are discussed. Both projects included the use of steel fibers in the mix, but otherwise varied significantly in methods and size.

The project at Reno had an area of approximately

19 100 m^2 (23 000 yd^2) and was bonded over an existing portland cement apron. The project at McCarran had an area of approximately 52 000 m^2 (63 000 yd^2) and was laid over an existing bituminous surface course with no attempt to bond. The major portion of the Reno project was 10.2 cm (4 in) thick, and the Las Vegas project was 15.2 cm (6 in) thick.

At Reno, the concrete was formed and employed the use of transit mixers, while at Las Vegas, it was central-plant mixed, slip formed, and hauled in standard dump trucks.

The work at Reno was on the apron adjacent to the terminal building and required some stage construction to allow continued aircraft movements. The work at Las Vegas was on the transient terminal apron, which was completely closed to aircraft so that it required no stage work.

Probably the biggest problem in handling fibrous concrete is that of introducing the fibers into the mix. It is a time-consuming process, and if it is not done properly, the fibers will have a tendency to ball in the mix. The fibers used at Las Vegas were delivered in forty 7.3-kg (16-lb) boxes, and when dumped out of the boxes, were found compacted and required separation. Through experience, it has been found that any change in direction of the fibers after separation on the shaker will create a tendency for them to ball up again.

The Las Vegas project used a single-drum central-plant mixer having a 4.6-m^3 (6-yd^3) capacity, but only 2.3 m^3 (3 yd^3) were mixed in each batch. Mixing time was 75 s. It was attempted to reduce the mixing time to 60 s, but the laborers were unable to handle the fibers rapidly enough. If a method could be devised that would allow more rapid introduction of the fibers, mixing times could be shortened.

One advantage of using a central plant and a slip-form paver rather than transit-mix trucks is that a better finished product is obtained because of consistency in the mix. Another advantage is that the use of a central plant and a slip-form paver appreciably reduces the labor force by eliminating the forming crew laborers required to set the forms and remove them and by approximately halving the number of finishers. Also, this method allows a lower slump [5 to 6 cm (2 to 2.5 in)], which is almost impossible to achieve from a transit mixer, that naturally upgrades the cement to water ratio.

The benefits of fibrous concrete override its problems. Reflective cracking is reduced appreciably in the thicker sections. The effect of adding fibers is to increase the flexural strength almost twofold. To meet Federal Aviation Administration criteria, the project at McCarran Airport would have required a 40.6-cm (16-in) mat of regular concrete, but with the use of fibers, a 15-cm (6-in) mat was acceptable.

However, these pavements should not be underdesigned, and the possibility of curling should be considered.

The additional flexural strength should also increase the life of the pavement section.