RESTORATION OF FINAL SURFACE TO CONCRETE PAVEMENT BY DIAMOND SAW GRINDING

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Diamond saw grinding, in 1965, first provided a final surface finish to an existing concrete highway. Improvements in diamond saw blades and grinding equipment during the past twenty years have made diamond grinding the most cost effective technique to restore riding quality and skid-resistance to a structurally sound concrete pavement. The data contained in this article is based on actual restoration work by various agencies, and is written to help the reader understand diamond grinding and how it is used in the Concrete Pavement Restoration, (CPR) process. Also included is criteria for determining when diamond grinding is needed, cost effectivness of the grinding process, and tips on achieving longevity of skid-resistance.

Diamond Grinding

An Alternative to Asphalt Overlays

A concrete highway is a dependable, durable product. It is a valuable asset and should be cared for properly. The rewards for such care will be longer life, less cost to the taxpayer, and a superior riding surface.

In the past, when oil was abundant and cheap, the asphalt overlay was the solution to virtually every road problem. It was routine to cover up deteriorated and out-of-tolerance surfaces with asphalt.

There is today a highly cost effective alternative to expensive overlays and it is called Concrete Pavement Restoration (CPR). It is a technique that was conceived, tested, and perfected over a period of years by such various groups as the American Concrete Pavement Assn., the International Grooving and Grinding Assn., and the Federal Highway Administration. The prime beneficiary of CPR has been America's Interstate Highway System.

Initially, contractors and diamond blade manufacturers worked closely in developing a new technology that permits such specially designed machines as the Target PRM 3804 to restore old concrete to a like-new condition. We in the trade call it "diamond grinding". Actually, diamond grinding is part of the over-all technique we call CPR. As many as eight steps may be employed to correct causes of pavement deterioration. This would include; (1) slab stabilization; (2) slab replacement, where needed; (3) repair of spalls; (4) resawing and resealing transverse and longitudinal joints; (5) shoulder restoration; (6) installation of edge drains, if needed; (7) diamond grinding; and (8) load-transfer re-establishment. It should be emphasized that not all of these steps may be required on every section of a highway scheduled for CPR.

Historical Highlights and Background

The Interstate System was designed to last for a given life cycle, based on its ability to carry a given but limited number of vehicle loads. In the 1950's design life was frequently estimated to be 20 years. However, the phenomenal growth of traffic in both volume and weight in the 1960's and 1970's, coupled with the decline of railroads as a means of hauling freight, placed an unanticipated weight burden on the system. The system was overloaded soon after it was put into service.

For example, it has been said that the Edens Expressway in the Chicago area carried 45 years of design traffic during a 28 year period. In a true sense, this road's ultimate performance far exceeded all expectations. And this can also be said of other sections of the Interstate System.

By 1970 it became quite apparent to federal and state highway engineers that steps had to be taken to save the system.

One of the pioneering states was Georgia. One of several individuals in the Georgia Department of Transprotation, (DOT), who was deeply involved from the very beginning was Ralph Allen, an expert in the design, placement and maintenance of concrete pavement. Allen was with the Georgia DOT from 1947 until he retired in 1982. He is now a consultant with MU, Inc.

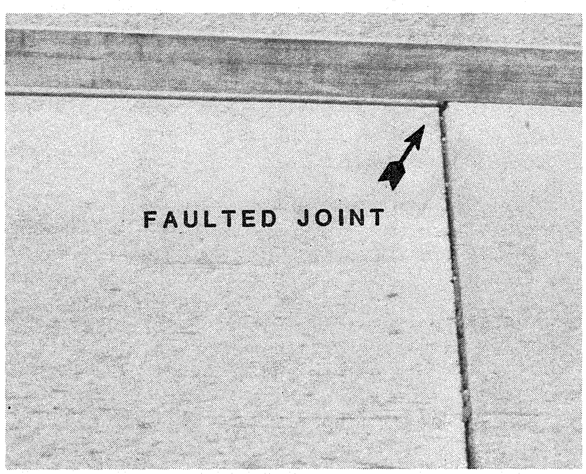
According to Allen, in 1971 the Georgia DOT initiated an annual highway condition survey to measure deterioration and to monitor its progression. The following year a task force was established to evaluate the Interstate System, to project maintenance needs and to assess the existing road design.

In terms of design, most highways built before 1975 in most states were quite similar. A 9-inch or 10-inch concrete slab was placed on a 6 to 8-inch thick bituminous stabilized sub-base. Also, joints were undowelled and spaced at 30-foot intervals. The shoulders usually had a 1-1/2-inch asphalt surface placed over a stabilized shoulder base. This was dubbed a "bath-tub" type design because it trapped beneath the slabs water that migrated through the leaking joint.

In 1973, the Georgia DOT proposed a new design which went into effect two years later. Here, a 9 or 10-inch concrete slab was placed on a 6-inch non-erodable, lean concrete sub-base. Transverse joints were, for the most part, variable, not exceeding 20 feet. In addition, the pavement contained dowelled joint reinforcement.

In 1974, Georgia's DOT continued to catalog such concrete slab problems as roughness, pumping, faulting, broken slabs, skid-resistance and the rate of slab deterioration. A search was begun for an effective joint sealant and experiments were made with edge drain installations.

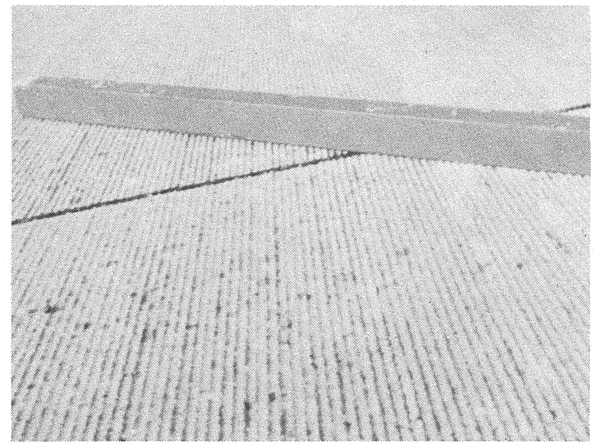
Photograph 1. Below, a 12-foot straightedge is used by Larry Mosher to show faulted joint in the truck lane.



In the following years, the state sponsored concrete restoration seminars and demonstrations. The Georgia DOT also experimented with concrete overlays between 3 and 6 inch asphalt overlays.

A possible alternative to overlays was seriously considered--that is , diamond grinding. The idea was that instead of resurfacing, old but structurally sound concrete could be ground to produce a level and textured surface equal to or superior to new concrete.

Photograph 2. Closeup area that has been ground. There is no damage to the joints with the diamond grinding technique.



An experiment in 1976 called for diamond grinding of 1-mile test sections on Interstate 75 near Perry and Interstate 85 north of Atlanta. These tests convinced state engineers that diamond grinding held considerable potential. As a result, the first large-scale experimental grinding project was then carried out involving 15 lane miles on Interstate 75.

By 1977, the Georgia DOT determined it would be economically feasible to use CPR on a wide scale Numerous contracts were awarded. In 1978, the state made a commitment to restore every mile of concrete of the Interstate System--approximately 1,200 miles. Probably more lane miles of concrete highways have been rehabilitated in Georgia than any other state. Apart from Georgia, CPR projects have been conducted in California, Arizona, New Mexico, Minnesota, Texas, Tennessee, North Carolina. New York, and many other states.

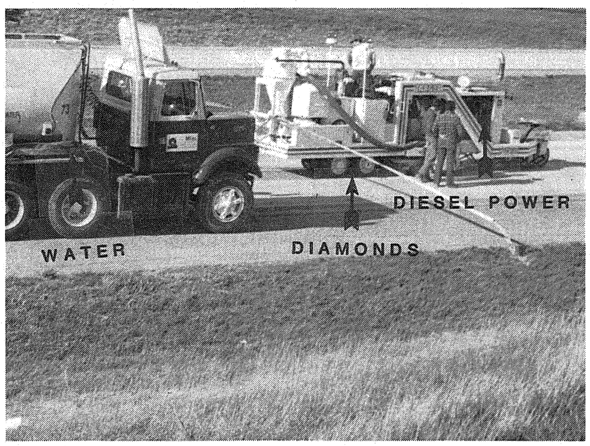
Actually, the first diamond grinding project of any magnitude was carried out late in 1965 when the state of California awarded a contract involving over 1,000,000 sq. ft. of a section of the San Bernardino Freeway (I-10). This section had approximately 19 years of heavy service, and there was faulting and slab curling. Diamond grinding successfully eliminated the faults and the curling, giving the road a second lease on life. However, it should be noted, the effects of pavement distress had been cured; but not the cause.

In 1983, the still structurally sound road got its third lease on life. The California DOT called for a total rehabilitation project that included slab replacement, spall repairs, the installation of edge drains, and diamond grinding. A total of 198,000 square yards of pavement were ground. In this particular case, diamond grinding has helped a concrete highway endure in service from 1946 through today---without benefit of an overlay.

The Process

When a concrete pavement is rough-rutted or slick, but otherwise structurally sound, diamond grinding is the most cost-effective technique to establish a final surface finish that provides a safe and comfortable ride.

Photograph 3. The diamond grinding process using 3 basic supplies...diesel fuel as a power source, diamonds for cutting, and water as a coolant/lubricant and waste remover.



In the diamond grinding process, diamond saw blades, either 12 or 14-inch diameter, are gang-mounted on a shaft. Usually form 50 to 60 circular blades per foot are required to produce a level surface with a corduroy-type texture. The cutting head is mounted under a machine designed to precisely plane and level concrete.

Photograph 4. Diamond blades being mounted on a shaft.

The water-cooled cutting assembly is surrounded by a vacumn pick-up bar. The system removes the cutting residue from the pavement surface and leaves the pavement relatively clean and dry. The grinding machines smooth faulted joints to an impact-free surface by shaving away the high side of the joint and blending it in with the low side.

Photograph 5. A Target grinder eliminates the ruts by removing enough concrete to re-establish the original pavement cross slope.

In diamond grinding, the water-cooled blades produce a slurry. Slurry is a combination of the water used to cool the blades and the concrete being removed. Chemically it consists of primariarly lime and water. Disposal of this slurry can affect the cost of grinding. From a contractor's standpoint, the most economical method is to discharge the slurry onto the grass slopes adjacent to the shoulder. The most costly approach is to haul the slurry away to some remote site, dig a trench and bury it. This is unnecessary and economically unsound. The lime slurry produced by grinding is a common additive employed to enhance the growth of vegetation. Because of its organic value, it should not be wasted. Slurry should not be left on the pavement to dry, as it will create a dusty condition, and if allowed to flow across the roadway, will cause a slippery condition. By all means, remove it from the pavement and discharge it onto the grass shoulder.

Photograph 6. The slurry, a mixture of the coolant water for the diamond blades and the concrete being removed, is discharged on the grassy slopes next to the shoulders.

Benefits of Diamond Grinding

Diamond grinding restores pavement cross-slope to the desired plane. This eliminates wheel path ruts caused by studded tires, improves pavement drainage, reduces hydroplaning, and prevents build-up of puddles in wet weather. The corduroy texture improves braking and vehicle directional stability. The grinding operation progresses systematically in rural or heavily traveled urban areas without impeding the flow of traffic. Only the immediate work area-often one lane-has to be closed. Many contractors have the capability of completing a lane mile of pavement in a normal work day.

The Georgia experience clearly indicates that ground pavement surfaces exhibit riding and skid-resistant characteristics equal to or superior to newly constructed pavements. New pavement is required to produce a ride number of 70 or less. Diamond grinding must produce 50 or less. In short, a diamond-rehabilitated road is superior in riding quality to a new road. Not only is a diamond-rehabilitated road superior in riding quality, but you also get more for your money. When diamond grinding versus asphalt overlaying, you get six extra miles for every ten miles for the same amount of money.

The Georgia repairs necessary to make an overlay cost-effective normally was in excess of $60,000 per interstate mile. The 4-inch thick asphalt overlay that was used was considered adequate but marginal and cost additional $250,000 per interstate mile.

The sections that were rehabilitated in Georgia through CPR cost considerably less. The normal preparation necessary to solve the basic problems and prepare for grinding often cost as much as $90,000 per interstate mile. The total cost of the concrete pavement rehabilitation including grinding usually cost about $155,000 per interstate mile, much less than the asphalt overlay cost.

The all-important point to the taxpayer--the heart of the matter, if you will--is road rideability. Will his car or truck ride smoothly? The discriminating driver will want to know if his vehicle will drive more safely or, in engineering terms, have a higher co-efficient of friction. Below is a summary of five concrete highway grinding projects carried out in recent years. Roughness index and friction numbers are provided.

TABLE 1

CPR PROJECTS
MAYS RIDE NUMBER

LOCATION	BEFORE	AFTER
Cullman,AL. I-65 - MP 308-316	118	58
Phoenix,AZ. I-17 - SB MP 202-213	126	37
Atlanta,GA. I-85 - MP 56-68	98	40
Newburg,NY. I-84 - EB MP 42-46	149	38
Rapid City,SD. MP - 50-66	92	37
AVERAGE 5 PROJECTS	117	42

Rides 2.8 times better.

TABLE 2.

CPR PROJECTS
SAAB FRICTION VALUE

LOCATION	BEFORE	AFTER
Cullman,AL. I-65 - MP 308-316	54	69
Phoenix,AZ. I-17 - SB MP 202-213	42	64
Atlanta,GA. I-85 - MP 56-68	45	95
Newburg,NY. I-84 - EB MP 42-46	40	85
Rapid City,SD. MP - 50-66	30	85
AVERAGE 5 PROJECTS		

A 90% Improvement

DATA FURNISHED COMPLIMENTS OF ROAD EYE, INC.

Factors Influencing Cost

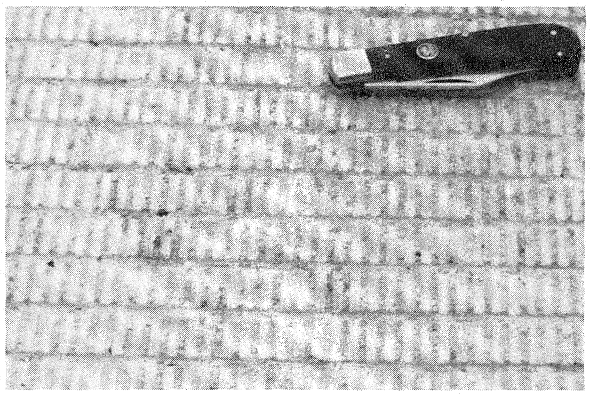
It is imperative that some state DOT's conduct a pavement survey to determine whether diamond saw grinding is feasible or even necessary. Highway engineers must collect data on such matters as the number of random cracks, shoulder conditions, the number of slabs with multiple cracks, the degree of faulting, and so forth. At the same time, it would be prudent to get a Pavement Serviceability Index reading. All of this data will ultimately determine whether diamond grinding is feasible.

If an existing roadway is structurally sound, has good skid-resistance, excellent rideability, but leaking joints, limited CPR is required. Only joint resawing and resealing are necessary. There is no sense in doing any diamond grinding. On the other hand, if 20% of the slabs on the roadway are busted or cracked, it would --- at the very least-- require slab replacement. The question that must be answered by the state DOT is, should the road be recycled or be given the CPR treatment?

To evaluate the process, you need to be able to estimate the cost of grinding. Without question, aggregate size and hardness have the greatest influence on diamond grinding cost. Cuttability of rock aggregates varies widely - from soft limestone on one end of the scale to tough river gravel containing a lot of chert, on the other. Hard rocks are understandably the most costly to grind and they require more diamond blades per cutting foot. Generaly speaking, it is wise to use between 55 and 60 diamond blades per foot when grinding hard aggregates. For soft stones, 52 to 56 blades are recommended. The number of blades per foot used help determine how long the texture will last.

Early attempts to grind large aggregates subject to polishing resulted in early loss of skid-resistance due to the fact that blades were spaced too close together. Here 60 blades per foot were used and no one, contractor or highway engineer, recognized the need to change the spacing on each project. The contractor should be given the perogative of deciding the number of blades that will best do the job and produce the texture the DOT desires.

Photograph 7. Combination of grinding and grooving.



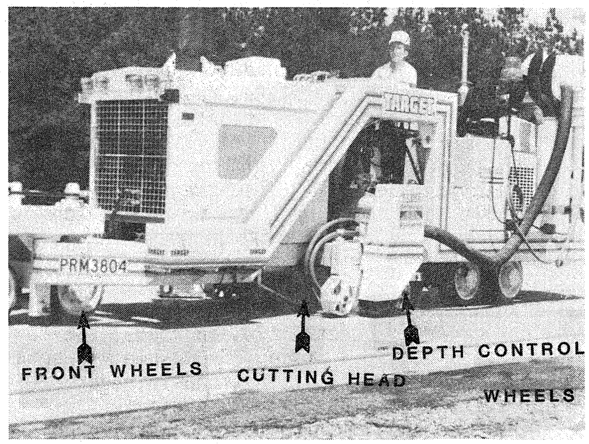
Speaking of large aggregates that are subject to polishing, something new has been tried and proven. After the roadway has been ground longitudinally, the pavement can be grooved transversely. Since the combination process is only needed in pavement with very soft aggregate, the cost of both grinding and grooving is low and the process is still cost effective. This combination of grinding and grooving produces additional benefits The pavement will drain very rapidly during periods of rain, and the grooving will leave a textured depth of 3/16 to 1/4 inch that will probably be adequate for skid-resistance after several years of wear. In fact, the author has observed grooved pavements over 10 years old in extremely polished aggregates that were maintaining an excellent skid-resistance.

The CPR Process

Is there a logical progression in the CPR process? Definitely! The first step is to replace the damaged slabs. Slab stabilization is next, followed by spall repairs. After this the installation of the retrofit load-transfer devices. At this stage, we have a 24 foot wide lane that is structurally sound.

We now bring on the diamond grinding machines. Most commercially available grinding machines operate on a rolling straightedge profilograph principle. That is to say, a long and narrow-frame machine whose depth control points ride within cut areas. Think of a diamond grinder as a shaving instrument. You can actually shave off .050 inch to .750 inch of road in a single pass, blending in the high spot and the low spot next to it. It is essentially a planing action. Most equipment is mounted on solid rubber tires, powered by diesel engines and equipped with one or more heads of diamond saw blades. Because of the unique hardness of diamonds, the hardest material known to man, there is a smooth abrading action. There is no pulling or tearing of mortar or aggregate. The tiny diamonds embedded in the periphery of the saw blade make very precise, minute cuts. Therefore, gradually, the high and low points are planed to a closer proximity, making a smoother riding surface.

Photograph 8. The grinder is like a giant wood plane; the front wheels ride over the bump; the cutting head shaves the bump away, and the depth control wheels ride in the level path.



After grinding, resaw and reseal all the joints. If the edge drains are required, they should now be installed. Carry out shoulder repairs, including the installation of sealed shoulder joints, preferably using a rubberized asphalt material. If a state DOT wants an asphalt shoulder removed and replaced with a concrete shoulder, this should be carried out at the time the slabs are replaced.

Diamond grinding should be continuous and uniform to achieve the highest degree of riding quality, skid-resistance and appearance. Some states feel it is necessary only to grind the truck lane, ignoring the passing lane which is generally in better condition. This is a mistake. If only truck lanes are ground, local traffic will gravitate to the right lane and avoid the rougher-riding passing lane. Remember, it cost far less to grind the passing lane than the truck lane. From a cosmetic standpoint, it makes sense to grind both lanes. This way you obtain a road of uniform color and appearance.

A question often asked by state DOT's is, "is it necessary to grind both the exit and entrance ramps?" The answer is no. There is merit in grinding the exit ramp for safety reasons. However, there is scant justification in grinding an entrance ramp where motorists are accerlerating and very rarely braking.

Acceptance Criteria

What are the options for acceptance of a CPR project and their effect on cost? The prime reasons for diamond grinding are to improve riding characteristics, correct cross-slope and increase pavement skid-resistance. It really is unnecessary to measure cross-slope and skid-resistance when diamond grinding is done. An inspector should be able to point out objectionable step-offs and abrupt edges that are sometimes found between passes of a machine! This can be spotted visually.

On the other hand, riding quality can and should be measured before and after a CPR project. A highway engineer can use a profilograph, a Mays meter, a Road meter or other device. The most obvious choice is a measuring device that shows consistent repeatability, one that is familiar to a particular state DOT, and one that takes consistent measurements in normal traffic or at normal traffic speeds. A profilograph is probably the most accurate of all but only the very latest electronic profilograph can be operated at normal traffic speeds.

Acceptance criteria can drive up the cost of diamond grinding. Some states have unreasonable acceptance criteria...for instance 1/8 inch in every 15 feet using a rolling straightedge. When contractors see such difficult or almost unachievable criteria, they will raise their price. This will enable them to go back and grind a second time.

Unfortunately, acceptance criteria varies from state to state. It seems reasonable that state DOT's should require from CPR what they require from new concrete construction on roads. It can be achieved, but at a price. From some viewpoints the ideal would be to have national standards of acceptance criteria for all CPR projects.

To sum up this difficult and sensitive point, state DOT engineers should ask for the same riding quality on CPR projects as they do on new concrete. The measurements should be made with a device that is safe to use and is consistant in performance. This is not to say that diamond grinding is suitable for all possible applications. If it is necessary to remove 2 inches or more for an overlay, diamond grinding should not be considered. It would be faster and more economical to use milling machines with steel or carbide tips.

Summary

The number one benefit of diamond grinding is improvement in riding quality. This is probably the only portion of a CPR project that John Q. Public truly appreciates. He couldn't care less about edge drains, new seals, spall repairs or new shoulders. He knows what road rideability is all about. Number two benefit is the re-establishment of cross-slope and the elimination of ruts. Number three is enhancement of skid-resistance. The fourth is reduction of impact loading on adjacent pavement, which will extend a roadway's life.

Once a Concrete Pavement Restoration project has been completed, the motoring public will enjoy a uniform, impact-free, skid-resistant surface that looks like corduroy and rides like velvet.