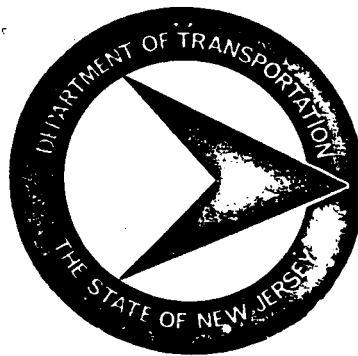


**SKID RESISTANT  
CHARACTERISTICS  
OF CARBONATE  
ROCK AGGREGATES**

by  
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**May 13, 1975**

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## ABSTRACT

This report reviews the several investigations of the polishing problems associated with carbonate rock aggregate.

The performance of this aggregate at many sites selected for investigation as well as its performance on test strip installations continually indicated that it polished to an unacceptable level of skid resistance more rapidly than did other aggregates commonly used in New Jersey.

With the acquisition of ASTM type skid testers it became possible to accurately measure the skid resistance of many miles of pavement. The further development of a prototype Skid Accident Reduction Program led to the use of wet weather accident data (an accepted indicator of slippery pavement) in uncovering problem areas. This system was used on 4093 miles of roadway in 1974. Sixty-four potentially hazardous sites were identified. Forty-eight of these sites were constructed with carbonate aggregate, and thirty-one of the sites so identified came from one aggregate supplier.

Concurrently, an investigation was instituted to determine the feasibility of a screening test which could identify the polishing rate of a carbonate aggregate prior to its use in a pavement. With the assistance of Rutgers University Geology Department, insoluble residues and thin sections were checked and some identifiable characteristics were determined. However, the procedure was very time consuming and would require additional trained personnel to administer.

When all the factors outlined in the report are considered, it is felt that both safety and economy call for a ban on the use of carbonate rock in bituminous concrete surface courses.

## Conclusions

The factors examined in this report indicate the following problems which are associated with the use of carbonate rock aggregate in surface course bituminous concrete.

1. A lower median level of skid resistance when compared with pavements constructed with other aggregates.

2. Accelerated polishing of the exposed aggregate under traffic wear.

3. As part of the Department's Skid Accident Reduction Program, criteria were established by which potentially hazardous sites could be identified. Using these criteria, 64 sites were pin-pointed on bituminous concrete pavements. Forty-eight (75%) of these potentially hazardous locations were constructed with carbonate rock.

4. The use of a screening test which would eliminate the more rapid polishing material is possible. However, it is extremely time consuming and would require impractical increases in manpower for both sampling and routine screening.

## Recommendations

After careful consideration of the factors set forth in this report, it is deemed necessary to recommend that carbonate rock be banned from further use in surface course bituminous concrete.

The elimination of carbonate rock from surface course will undoubtedly cause some increase in the Department's annual construction costs (less than \$100,000 estimated for 1974). However,

this increase should be more than equalled by the gain in safety benefits to the driving public and the reduction in future expenditures for corrective anti-skid overlays.

### History

Various methods for eliminating problems due to polishing of some carbonate aggregates have been pursued by the Department of Transportation in the past.

In the 1950's a ban was placed on the use of New Hope produced dolomite in surface course bituminous concrete. The files do not indicate how long this ban was in effect or why it was rescinded.

In 1965 the State Highway Engineer directed the Division of Research to initiate an investigation of all projects constructed in the preceding five years in which dolomite constituted the aggregate used in the surface course. The detailed results of this study are documented in a report titled "Relative Skid Resistance of Bituminous Concrete Pavement Surfaces Containing Dolomite Coarse Aggregates" (copies of this and other reports cited are on file with the Division of Research and Development). This study was to evaluate the history of each project in relation to slippery pavement. A second aim was to develop a means by which the coefficient of pavement friction, or other index, could be measured and compared with non-dolomitic surfaces. It was also intended to evaluate differences in the physical properties of various sources of dolomite available to the State.

At the time of the 1965 investigation, New Hope Crushed Stone & Lime Co. was providing 70% of the dolomite used in the State and G & WH Corson-Plymouth Meeting was supplying 25%. The report therefore focused on these materials and compared them with trap rocks from Bound Brook and Kingston. Results of skid measurements and accident data analyses indicated that Corson was markedly more skid resistant than New Hope under like conditions and better than the trap rock from Bound Brook on the average. However, even this material polished below acceptable values at some locations as did the basalt trap rock from Bound Brook. Only the diabase from Kingston was completely satisfactory at all sites. Because of the variability of carbonate rock the report recommended investigation of means for predicting polishing rates of aggregates. Suggested for further study were petrographic analyses and/or identification of insoluble residue after acid reduction of the aggregate.

In the summer of 1961, a number of test sections were placed on the northbound lanes of Route 1 in Lawrence Township. In September of the same year New Hope Crushed Stone & Lime Co. contributed material for some six test sections which were placed in the southbound roadway. In these sections dolomite was used both alone and blended with various other aggregates in order to determine whether or not its skid resistant properties could be improved. A report was issued (Evaluation of Skid Resistance Characteristics of Thin Bituminous Overlays).

At the completion of the Route 1 study, after more than 5 million vehicle passes, none of the dolomite sections exhibited a satisfactory level of skid resistance. The average skid numbers for the outside lanes ranged from a marginal 34 for a blend of dolomite coarse aggregate with concrete sand to an average of 25 for a dolomite, concrete sand, boiler slag blend. This past summer, after an estimated 18 million vehicle passes, all of the test sections exhibited approximately the same skid resistance as they did at the completion of the study.

### Field Tests

In 1971 some 1,300 miles of pavement were skid tested in the initial phases of the Department's inventory program. The results of this testing showed an average skid number of 37 (range of material by source 31-44) for 335 tests on bituminous concrete with carbonate rock aggregate. For trap rock the average skid number was 41 (range 34-54) for 1138 tests. There were also 175 tests run on bituminous concrete with gneiss coarse aggregate. The average skid number for these tests was 40 (range of averages 36-48 for 6 quarries).

In 1974 the skid inventory program resulted in skid measurements being made on 4093 miles of pavement on the state and interstate systems. The data collected in this inventory was combined with accident data in order to provide the basis for a Skid Accident Reduction program. This type of program is required by the Highway Safety Program under Standard 4.4.9. The criteria

established for the identification of a potentially hazardous location was a combination of average skid number per test mile of 30 or less together with a wet weather accident rate of 10 or greater. This wet weather accident rate is calculated as

$$\frac{\text{Wet Weather Accidents X 10,000}}{\text{AADT/\# of lanes}}$$

Using these criteria, 64 sites were identified on bituminous concrete pavements. An inspection of these sites together with a check of construction records where available, disclosed that 48 of these locations were constructed with carbonate aggregate, 10 sites constructed with trap rock, 5 with gneiss and 1 site had been resurfaced after the skid survey. Further, 31 of the 48 carbonate sites were identified as New Hope carbonate.

#### Laboratory Tests

At the end of 1972 a number of samples from carbonate rock sources were submitted to the Bureau of Quality Control in order to evaluate the efficiency of a New York State method for determining the amount of insoluble residue present in carbonate aggregates (N.Y. 225-69). Insoluble residue was believed to be an indicator of polishing resistances for such aggregates. It was expected that the higher the amount of insoluble residue the better would be the resistance to polishing. In a January 1973 memorandum, Mr. Andres indicated that the New York State method was semi-quantitative at best and was very time consuming.

He suggested ASTM C-25 as a more reproducible and quicker procedure for determining insoluble residues. Also suggested was the use of lithologic examinations to identify polish prone aggregates. Some 15 sites which had been skid tested previously and were known to range from non-slippery to slippery were cored. The coarse aggregate was extracted and the fractions from the surface course were submitted for determination of insoluble residue contents.

The results of this analysis were inconclusive with no real relationship being found between the percent of insolubles and the skid resistance of the surface. Failure of the two parameters to correlate may have been due to the C-25 procedure which utilizes a 0.5 gram sample and requires manual grinding of the material so that it passes a No. 100 sieve. This saves time in the acid reduction but also allows a large amount of exceptionally friable material to be included in the final insoluble residue. This material is of little or no value in improving skid resistance.

In a continued search for a useful screening test to identify polishable carbonates, contact was made with Rutgers University Geology Department to determine their interest in providing technical and laboratory testing assistance to the Department of Transportation. As a result of this discussion a contract was let for consulting services from Rutgers whereby they would examine samples from a minimum of ten locations in order to determine if any means for forecasting the polishing rates of carbonate aggregates could be established. (Copy of contract with Rutgers is available). This

investigation is still in progress and is being performed by Mr. Warren Cummings, Assistant Geologist with the Department. He is a graduate student at the University and is working under their tutelage. This has served the dual function of increasing the Department's expertise in this area as well as making use of the knowledge and equipment available to the University.

Attached are two reports prepared by Mr. Cummings. The first, "Laboratory Investigation - Skid Resistance Properties of Carbonate Aggregates, Summary of Activities and Finding to January 1974" is a preliminary report dealing mainly with the laboratory phase of the investigation. The second report, "Preliminary Report As to the procedure Required to Predict the Eventual Skid Resistance of Carbonate Aggregates" discusses the procedures necessary to predetermine the final degree of polish of carbonate aggregate. It is based on one season's evaluation of these procedures on selected projects in the field. Briefly, the report indicates that a measurement of four properties of the coarse aggregate will allow for prediction of skid numbers within broad limits. However, the measurement process is a time consuming one that is presently beyond the physical capabilities of the Bureau of Inspection. It is not unreasonable to expect that the Department of Transportation could eventually obtain the equipment and expertise necessary to perform the screening tests developed by Mr. Cummings. However, the fact that the test can not be accomplished quickly could pose insurmountable problems. A producer might stockpile a large quantity of material which could not

be approved for State work until the testing was completed. If it was not approved, he would have to once more stockpile material and repeat the entire process. The time delay for approval would (optimistically) range from two weeks to a month. Because of the variability of carbonate rock, especially from New Hope, each and every stockpile would have to be sampled. As pointed out in the second report, the many problems associated with the implementation of this screening procedure must be weighed against the availability and costs associated with other aggregate sources.

### Polishing Rates

Another factor to be considered is the number of vehicle passes which various aggregates can sustain without polishing to an unacceptable level of skid resistance. Skid numbers and associated vehicle passes were determined for some 80 locations using trap rock aggregate, 50 locations using carbonate rock and 33 sites with gneiss as the coarse aggregate. Regression analyses were performed separately on these three aggregate types with skid number as the dependent variable versus traffic as the independent variable. The regression line for carbonate rock (attached) shows a marked deterioration of skid number with polishing under traffic. This relationship is not seen at all with trap rock and to a much lesser degree on the gneiss sections. Although the variability of the data, together with the relatively limited number of sites, does not allow the use of these regression curves as predictors, they do illustrate the general polishing trends. The use of carbonate rock aggregate in the surface course does imply a more rapid decay of skid number with cumulative vehicle passes.

Economic Impact of Ban on Carbonate Rock

A review of the anticipated economic impact of eliminating carbonate rock from surface course follows. This is based on data from the 1973 construction season for all Department of Transportation projects including state aid work.

A. FHWA Participating and Straight State Funded Projects.

Region 1

Little or no carbonate rock used in construction.

Region 2

Little or no carbonate rock used in construction.

Region 3

|                                                    |              |
|----------------------------------------------------|--------------|
| Total Coarse Aggregate used in Bituminous Concrete | 600,000 tons |
| Carbonate Rock used in Bituminous Concrete         | 24,000 tons  |
| Coarse Aggregate used in Surface Course            | 130,000 tons |
| Carbonate Rock used in Surface Course              | 14,300 tons  |

Increase in stone cost if Carbonate Rock were banned from:

|                         |          |
|-------------------------|----------|
| All Bituminous Concrete | \$24,000 |
| Surface Course only     | \$14,300 |

Estimated Increased Trucking Costs

Costs per ton mile: N.J. = 0.12      Penna. = 0.07

Weighted Average length of haul: (quarry to center of region)

Trap Rock, 30 miles

Carbonate Rock, 42 miles

|               |                                          |
|---------------|------------------------------------------|
| All Carbonate | $.07 \times 42 \times 24,000 = \$70,560$ |
| Top           | $.07 \times 42 \times 14,300 = \$42,042$ |
| All Trap Rock | $.12 \times 30 \times 24,000 = \$86,400$ |
| Top           | $.12 \times 30 \times 14,300 = \$51,480$ |

Total Increase (Stone and Trucking)

|             |          |
|-------------|----------|
| All Courses | \$39,840 |
| Top Only    | \$23,738 |

Region 4

|                                                    |             |
|----------------------------------------------------|-------------|
| Total Coarse Aggregate used in Bituminous Concrete | 54,033 tons |
| Carbonate Rock used in Bituminous Concrete         | 17,615 tons |
| Total Coarse Aggregate used in Surface Course      | 22,889 tons |
| Carbonate Rock used in Surface Course              | 6,455 tons  |

Increase in cost if Carbonate Rock were banned from:

|                         |          |
|-------------------------|----------|
| All Bituminous Concrete | \$17,615 |
| Surface Course Only     | \$ 6,455 |

Estimated Increased Trucking Costs

Weighted average length of haul to center of region. Carbonate 55 miles,

Trap Rock, 70 miles

|                    |                                           |
|--------------------|-------------------------------------------|
| All Carbonate Rock | $.07 \times 55 \times 17,615 = \$67,818$  |
| Top                | $.07 \times 55 \times 6,455 = \$24,852$   |
| All Trap Rock      | $.12 \times 70 \times 17,615 = \$147,966$ |
| Top                | $.12 \times 70 \times 6,455 = \$54,222$   |

Total Increase (Stone and Trucking)

|                 |          |
|-----------------|----------|
| All Courses     | \$97,763 |
| Top Course Only | \$35,825 |

Local Government Aid Projects

If, in addition, the ban were to include State Aid projects:

District 1 and 2 - no carbonate rock

District 3 - Total increased cost = \$12,450 (7,500 tons)

District 4 - Total increased cost = \$24,400 (4,630 tons)

Summing up the preceding data, 919,000 tons of material were used in 1973. If we use the average weighted price of \$14.35 per ton, the cost would be \$13,188,000. The anticipated total increase in price resulting from a ban of carbonate rock was \$174,453 or 1.3 percent. This is a worst case estimate, assuming that a ban on carbonates in surface course would also result in their not being used in base courses. If use of carbonates in base layers continued after such a ban, the cost increase would be substantially smaller, probably less than \$90,000.

Some of the other factors whose impact cannot be evaluated are worth mentioning. First, increased trucking and possible return loads of sand from the South Jersey area might result in lower trucking costs. Secondly, partial shipment by rail would have an effect. Third, the decreased competition resulting from a ban on carbonates might result in an increase in price for the permitted aggregates. Mitigating against this is the fact that the ban could be rescinded at any time.

Finally, all carbonate rock sources are outside the State of New Jersey. A ban on carbonate rock would thus have the effect of increasing the aggregate demands on in-state sources. This increased demand should in turn have a beneficial effect on the state's economy as the New Jersey aggregate industry is currently working at a reduced level.

REFERENCES

1. "Relative Skid Resistance of Bituminous Concrete Pavement Surfaces Containing Dolomite Coarse Aggregates", Division of Research and Development Report - 7760518.
2. "Evaluation of Skid Resistant Characteristics of Thin Bituminous Overlays", Division of Research and Development Report - 7772518.
3. Memorandum from C. J. Andres to K. C. Afferton "Evaluation of Acid Insoluble Residue Tests for Carbonate Aggregates."
4. Contract between the State of New Jersey and Rutgers College, Department of Geology - August 15, 1973.
5. "Laboratory Investigation - Skid Resistance Properties of Carbonate Aggregates. Summary of Activities and Findings to January 1974" - Copy attached.
6. "Preliminary Report As to the Procedure Required to Predict the Eventual Skid Resistance of Carbonate Aggregates" by Warren Cummings - Copy attached.

**Laboratory Investigation**  
**Skid Resistance Properties of Carbonate Aggregates**  
**Summary of Activities and Findings to January 1974**

Skid resistance has been the subject of sporadic investigation in the United States for over 20 years. In that time, considerable material has been published concerning the many factors which affect this phenomenon. The most important of these factors is pavement texture whose basic precursors are the lithology and microstructure of the coarse aggregate.

Several previous investigators have shown skid resistance to be produced by adhesion and deformation responses to tire-pavement interaction. Both these friction-producing processes are directly related to the macrotexture of the pavement surface. In addition, adhesion is directly related to microtexture.

Texture is a descriptive entity encompassing the density, height, and angularity of protrusions above the pavement surface. Most investigators arbitrarily set the boundary between macro and micro features at 0.2 mm of amplitude.

Previous investigations have shown that, as pavements wear, macrotexture becomes greatly reduced in a relatively short period of time; as little as three months. With pavement aggregate at or near its maximum degree of polish, adhesion and deformation forces are reduced. If, however, the aggregate degrades so as to constantly renew a substantial amount of microtexture, the resultant adhesion has been found to produce adequate skid resistance.

Therefore, the main goal of this current research is to determine what characteristics of the aggregates: (1) impede the rate of polish; and more importantly (2) produce a degradation that retains a high level of microtexture.

The first step of the current investigation was to estimate the effects of lubricating contaminants which would mitigate tire adhesion. Culpable agents considered included oil, tire rubber, smeared asphalt binder, and possibly clay derived from the aggregate.

Evaluation was done visually by examination of the preserved cores and inspection of the pavements in place. No significant amounts of lubricants were found outside the usual mid-lane oil streak. Insoluble residues were checked by X-ray diffraction for clay with negligible results. Clay was never more than a trace lost in quartz and feldspar. The author concluded that the skid numbers from the trailer and the British portable meter reflect textural effects with minimal side effects.

The next procedure was to determine what petrographic features of the aggregates in question would substantially affect pavement texture. Initial petrographic examination has concentrated on thin sections made from extracted aggregate in epoxy. A detailed description of the geology of the four aggregate sources and the petrography of the samples is beyond the scope of this report, but a few prime considerations are as follows:

Overall carbonate grain size distribution is remarkably similar for all but one sample. The typical carbonate matrix is composed of densely packed, blocky dolomite crystals from .0025 mm to .050 mm in size with occasional larger anhedral crystals. Aggregate pieces composed solely of this material tend toward a high, sometimes glassy, polish. The effect of increasing discontinuity of grain size has yet to be evaluated fully.

Layering, due to mineralogical and/or grain size differences (lamination and foliation), is a prominent feature in many of the samples. Examination of the extracted aggregate and the pavement cores with a binocular microscope shows that layering is particularly effective in producing rough grain surfaces.

Fractures, rehealed by relatively coarse grained  $C_2CO_3$ , are fairly common in some samples. The effect is similar to layering--putting different grain sizes adjacent to each other. Calcite veining does produce surface roughness in the crushed material, but its performance under pavement surface wearing conditions must be evaluated in the next phase of the project.

Insoluble residue, primarily quartz sand and silt, has been directly correlated with skid resistance by many investigators. Insoluble residue results from the aggregates in question here show a poorly defined, but recognizable correlation with skid resistance; however, the most anomalous points can be explained in terms of another parameter, such as grain size.

#### Future Endeavors

The next step to be taken will involve thin section study of the pavement wearing surface. Sections will be prepared in the manner described by Webb (1970) and hopefully will provide a method for evaluating the effect of the above parameters on wearing characteristics. It will also provide a method for quantitatively evaluating surface texture.

Preliminary Report As To The Procedure Required To Predict The Eventual Skid Resistance Of Carbonate Aggregates by Warren Cummings

Investigations into the development of slipperiness on bituminous concrete surfaces constructed with carbonate coarse aggregate has indicated 4 measureable properties of the coarse aggregate which effect the eventual degree of polish. These 4 variables are as follows:

- (1) Percentage of + #200 mesh acid insoluble residue.
- (2) Percentage of coarse aggregate, + #8 sieve, other than carbonate.
- (3) Overall mean grain size or percentage of predominately coarse grained lithologies.
- (4) Percentage of laminated coarse aggregate fragments.

Determination of these variables requires acid treatment and petrographic thin section analysis by a procedure roughly outlined as follows. They do not represent the whole story but enable prediction of skid numbers within broad limits.

A. Field Work

- I. Material for Job "X" stockpiled at quarry or asphalt plant (stockpile shape, size, etc. may have to be specified).
- II. Thorough, ritualized sampling of the stockpiles entire perimeter using a front end loader.
  - a) one forty pound bag per 1000 tons.

B. Testing

- I. Split out a 500 gram sample, per bag, of + #8 material.
  - a) Divide 500 g. sample into 50 g. units.
- II. Dissolve 4 of the 50 g. units in conc. HCL individually
  - a) when action stops neutralize with  $\text{NaHCO}_3$  and decant liquid
    1. dry the residue
  - b) weigh dried residue.
  - c) wash residue through a #200 mesh sieve.
  - d) collect + #200 mesh material, dry, and weigh.
  - e) calculate percent of + #200 material and average the 4 results.
  - f) if the 4 results are widely divergent, re run the process using 4 more 50 g. units.
- III. Construct 2 grain mounts of + #8 aggregate in a suitable epoxy using 2 50 g. units.
  - a) make 3 thin sections per grain mount.
  - b) analyze sections petrographically to determine:
    1. grain size distribution
    2. lithologic distribution
  - c) If material is highly variable more grain mounts and thin sections should be made until a statistical pattern is established.

IV. Estimate skid resistance potential (methodology for this is still being refined)

V. Approve material or reject with recommendations for corrective action.

Because of the variability of some aggregate sources, especially New Hope Crushed Stone, evaluation would have to be made on a stockpile by stockpile basis.

The analytical process, particularly the petrographic work, is time consuming and quite tedious. The time required to complete a set of samples depends on several factors. The most important of which is the rate of sample influx.

Under ideal conditions a complete analysis might be made in  $1\frac{1}{2}$  to 2 weeks. This assumes that the author would make the thin sections using equipment at Rutgers U., as has been the case previously during M. S. Thesis work on skid resistance. It also assumes no diversions of the author's time and no mishaps along the way. Time requirements per stockpile would be at least 24 hours per 1000 tons (1 bag sample) & travel time etc. If the samples are sent to a commercial thin section preparer (approx. \$2.75/section), as has been done in a previous Bur. of Insp. program, analysis would take a month. In the case of a rejection, the procedure would begin all over again after a new stockpile had been built.

Currently the author is the only employee of the Bur. of Insp., and probably the entire D. O. T., qualified to do petrographic analysis and make thin sections. Due to the time required for the various procedures involved an influx of more than 2 or 3 one bag samples a week would amount to an overwhelming load.

Finally, there has been some reluctance in the past at the Bur. of Insp. to embark on programs involving stockpile by stockpile approvals due to the strain on personnel resources and control problems.

#### Conclusions

Skid numbers can be predicted within broad limits by measuring 4 properties of the coarse aggregate. The measurement procedure is time consuming and tedious and could easily overwhelm the capacity of the Bur. of Insp. to digest the samples. The potential for confusion delay and entanglement in red tape is high especially in the case where material was rejected. It is the opinion of the author that instituting carbonate rock approval for surface course use on the basis outlined above will create many problems to be weighed against cost and availability factors in general aggregate supply.

#### Appendix #1

(A) Explanation of variables mentioned in the main text.

1. + #200 mesh insoluble residue:

This is the material which remains after the reaction of carbonate rock with Hydrochloric acid. In all the cases examined thus far the residue has consisted mostly of quartz with lesser amounts of mica and traces of feldspar and clay. Other minerals are rarely seen.

The insoluble material is unevenly distributed, in both size and amount, among the aggregate fragments. Concentration of the insoluble in a few pieces tends to reduce expected skid resistance.

Insoluble residue in carbonate aggregates has long been recognized as having a direct effect on skid numbers but this effect has been poorly quantified. The relationship apparently holds for materials which have been used in New Jersey. A plot of skid number vs. +200 insol. residue yields a scattering of points through which a straight line trend can be constructed. The considerable scatter can be attributed to the combined effects of other aggregate and pavement variables. The average trend is approximately I.R.= 1/3 (SN<sub>40</sub>)-8.3 or I.R.= .38(B.P.)-18.8.

Therefore insoluble residue is apparently the major variable although its effect is modified by other factors.

2. Aggregate other than carbonate rock:

There are three significant items in this category: (1) Quartz from the +#8 sieve fraction of the fine aggregate (very coarse sand), (2) large quartz fragments from flint patches or veins (at Downing Town), (3) Trap rock from the 15 foot thick dike at New Hope.

These materials have a small tendency to improve skid resistance. In small amounts they may be considered part of the insoluble residue.

3. Mean Grain Size:

A preponderance of coarse grained lithologies tends to have a positive effect on skid resistance, especially when insoluble residue is low. In the one case examined by the author an aggregate from G. & W.H. Corson with a very low insoluble content gave a moderate skid number. The aggregate's only anomalous feature was a mean grain size at least twice as great as all other samples examined. The larger grain size resulted in a sugary wearing surface texture.

4. Laminated aggregate fragments:

These are aggregate pieces which contain very thin layers of different lithologies such as concentration of quartz sand or mica or various grain sizes. The result is differential wear and a broken surface which would tend to improve skid resistance. The author has not yet seen a case where there was enough of this type material to be significant.

(B) Other variables exist which effect skid resistance. The most important these are (1) grading of the fine aggregate, (2) asphalt content and bleeding, (3) surface contaminants, and (4) overall pavement microtopography, especially undrained pits and depressions. See Schonfeld; ont. D. H. Rept #RR 155, 1970

*Norman Cummins*

Bur. of Inspection

9-23-74

# CARBONATE ROCK

