MATES

MICHIGAN DEPARTMENT OF TRANSPORTATION

Issue No. 23 September 1988

THE ORIGIN OF NATURAL GRAVEL DEPOSITS AND THE EFFECT OF CRUSHED PARTICLES ON AGGREGATE STABILITY

The Michigan Department of Transportation currently has specification requirements for 26 different coarse and dense graded aggregates. They are used in portland cement concrete for roads and structures, for bituminous pavements, for bases under concrete and asphalt roads, for gravel roads and shoulders, and many other uses. Each aggregate class is designed for specific uses and has separate physical requirements, one of which is the percent of broken or crushed particles.

An aggregate, by definition, is a manufactured material. Aggregates in Michigan are made from natural gravel deposits, stone quarries, blast furnace slag, steel furnace slag, reverberatory slag from copper smelting, and crushed concrete.

Except for quarried aggregate, crushed concrete and slag, the crushed content of the various aggregate classes will vary widely. Aggregates derived from natural gravel sources are a product of the action of continental glaciation. The glacial ice, as it slid and ground its way across the land surface, picked up, ripped out, and plucked pieces from the exposed bedrock surface.

These rock pieces and fragments became incorporated into the bottom part of the ice mass. As they moved along with the ice, they were broken, ground, and some were reduced in size from boulders to various sizes of rock, sand, and a very fine dust called rock flour. In this initial condition, most of the aggregate size particles would be considered as nearly 100 percent crushed.

When the ice ceased to flow forward and began to melt, part of the mixture of ground up rock particles was carried by the meltwater and deposited in a variety of what are called glacial fluvial deposits. These are the sand and gravel deposits which are a major source of our construction aggregates.

The particular types of rock fragments are mixtures of all the rock types picked up by the ice. The softer, less resistant rocks are ground and pulverized to clay, rock flour, silt, and sand. The harder, more resistant types such as igneous and metamorphic rocks generally survived the long trip from Canada. While they constitute less than approximately 5 percent of the total glacial drift, these harder rocks were concentrated by the meltwaters to make up 40 to 60 percent of the stones in a typical gravel deposit in the southern half of Michigan's lower peninsula.

As the angular rock particles were tumbled and rolled along in the meltwater streams and rivers flowing from the melting ice, their sharp edges quickly started to become rounded and rough faces became smoother. Studies have shown that an angular rock particle will become principally rounded after being carried three miles through the abrasive action in a stream or river. Rock particles as they are eroded by abrasion tend to approach a round or oval shape as this provides the greatest volume for the least surface area, a condition that nature prefers.

Smooth, rounded rock particles, whether they are coarse aggregate size or fine aggregate size, have poor stability when incorporated into an aggregate base course or a bituminous mix. Rounded individual particles act like marbles or BBs and slip and slide around and fail to mesh into a stable mass. When aggregates are designed to form a stable mass and support loads, rounded particles must be avoided or used in minimum proportions.

If rock particles have flattened sides, their ability to slip and slide and tumble over each other begins to diminish as one flattened side mates up with another. As the sides become increasingly flatter and more angular, the stability becomes better and better until an extremely stable layer is formed. This is why there are specifications for the percent of crushed particles in certain aggregates used in building road bases or pavements where strength and stability are required.

Studies have been made as to the type of crushed face and edges (fresh face, sharp edges vs. smooth face, rounded edges) that are necessary to achieve the desired stability. The results have indicated that fresh fractures with rough faces and sharp edges yield the greatest stability. Incidentally, it isn't important whether a rock particle has been fractured by glacial action or by a crusher at a gravel plant. The origin of the crushing should not be a consideration when 'picking' aggregate particles for crushed content.

The term pick or picking is used when individual aggregate particles are identified and separated from a sample for a specific purpose. There are picks for crushed content and picks for deleterious (poor aggregate) content. The proper way of picking crushed particles is an important part of aggregate testing and quality control. The crushed requirements of a particular aggregate class are put there for a reason and constitute a critical part of an aggregate's composition.

When edges are more rounded and fractured faces are smoother, the stability, although better than fully rounded, significantly decreases. Therefore, a crushed particle as defined for MDOT procedures is one with a freshly fractured face with sharp or slightly blunted edges. It is noted that very sharp edges begin to become blunted with handling. This is particularly true of relatively soft particles such as limestones and dolomites. If the edges are only slightly blunted, but not rounded, they should be picked as crushed.

A rock particle with a chip or small fracture on one side does not constitute a crushed particle. The fracture must involve a significant part of the particle. This is a judgment call. As a guide, if the rock particle is held so that its fractured face is viewed directly, the fractured part should constitute at least 50 percent of the outline of the rock particle. Depending upon the particular class of aggregates, an individual aggregate particle may be required to have at least one or at least two crushed faces.

In picking for crushed particle content, the aggregate is separated into two piles of obviously crushed and obviously uncrushed particles. This leaves a third pile which is questionable. One-half the weight of this questionable pile is then added to the weight of the crushed pile and the other half added to the weight of the uncrushed pile. Experience has shown that the weight of the questionable pile should be less than 20 percent of the weight of the total sample.

One exception to the crushed particle identification is sandstone. Regardless of its shape, a sandstone particle is always picked as a 100 percent crushed particle. This is because the individual sand grains in the sandstone act like crushed particles or like sandpaper would act against an adjacent particle.

It is evident that an aggregate is a very special manufactured material. Depending upon its uses it can have varied physical requirements of gradation, crushed content, deleterious limitations, and other such requirements as freeze-thaw durability not mentioned in this article.

-Don Malott

IMPORTANT UPDATE!

Subsequent to publishing the article RESTRICTION ON FOREIGN MATERIALS in the last (Issue No. 22) MATES, an advisory was received from the Federal Highway Administration clarifying the official interpretation of a 'foreign product.'

Two examples were given in our MATES article as to the interpretation of the term 'product.' The first example defined portland cement concrete as a 'product,' rather than any of its constituents; therefore, if portland cement costs less than half the cost of the concrete, foreign cement could be used. The second example involved the use of a Japanese reflective sheeting material for signs. We interpreted the sign to be the finished product, and its cost would include the wood or metal backing, the labor to build it, and the sheeting. Thus, if the foreign sheeting cost less than 50 percent of the total sign cost, it could be used.

The Federal advisory apprises that this is only partially correct. In the first example cited above, if the contractor or subcontractor buys ready-mixed concrete, use of foreign cement would be permissible providing it constituted less than 50 percent of the cost. If, however, the contractor manufacturers his own concrete, purchase of foreign cement would not be allowed, as the foreign cement is now the purchased product. In the second example; again, if the complete sign is purchased for erection by the contractor or subcontractor, it is permissible to use the Japanese sheeting providing its cost is less than half the cost of the sign. On the other hand, if the sign fabricator is the prime contractor or a subcontractor, the reflective sheeting used for the sign would be the product, and would not be acceptable if made in Japan.

-Ralph Vogler

HOT-MIX BITUMINOUS RECYCLING - MAKES SENSE AND SAVES DOLLARS!

Much has been written concerning bituminous pavement recycling and the effect it's had on modern paving practices. We thought that MATES readers might be interested in a 'brass tacks' look at the benefits derived from hot-mix bituminous recycling procedures, based upon 1985 construction season data. Michigan did its first hot recycling job in 1977 and since then the process has become increasingly popular.

Materials. Whenever one is able to recycle, a natural resource is left intact. Aggregate materials that were conserved through recycling in the 1985 construction season amounted to 525,000 tons; thus, that quantity of our gravel reserves did not have to be tapped. Asphalt cement savings amounted to approximately 10,500 tons, so that less new petroleum products were required. Since recycling involves removal of the old pavement, either entirely or partial depth, it is possible to maintain the existing cross-section. Conventional overlay construction requires more shoulder material to maintain the shoulder-pavement plane, reduces curb height, eventually requires raising of guard rails, and suffers from reflection cracking. When the entire pavement is removed, reflection cracking is entirely eliminated, the public has a new roadway, and the materials can be recycled on the job from which they were removed as well as used for others to be built later.

Dollars Saved. Reuse of the 525,000 tons of aggregate in 1985 saved the Department from 1.5 to 2.5 million dollars, based upon a new aggregate price of $3.00 to $5.00 per ton. A conservative estimate of the dollars saved by reuse of the 10,500 tons of asphalt cement would be about 2 million dollars.

Quality Control. When the criteria that 100-percent new material mixtures must satisfy are applied to recycled mixtures, we find that all of them are in the 'meet' or 'exceed' range. For example: recycled top course mixtures are typically higher in measured stability than mixes tested with the same materials without the addition of the reclaimed pavement (remember, recycled mixes are not made of 100 percent recycled material, but virgin aggregate and asphalt cement with recycled material added). The percent of bitumen in the mixture shows 100 percent of design content in both new and recycled mixtures. The penetration of recovered bitumen figures from recycled and virgin mixes are so close to identical that there may be no practical difference.

Thus, in considering simply tons/dollars/quality figures from one season's hot-mix recycling projects, one can see the advantages of using this method wherever possible. As with other new technology, as each season passes, refinements will undoubtedly take place and dollars will continue to be shaved from the costs of upgrading our bituminous pavements through hot-mix recycling.

-Ted Hanlon

TECHADVISORIES

The brief information items that follow here are intended to aid MDOT technologists by advising or clarifying, for them, current technical developments, changes or other activities that may affect their technical duties or responsibilities.

NEW MATERIALS ACTION

The New Materials Committee recently:

Approved the following products:

- Rawl Chem Stud for Concrete Anchors
- Tiger-Tite Locking Rings and Pliers for Gabions
- Grade Adjustment Rings for Manhole Covers
- MSU #360 Alu Poly Manhole Step
- Drainage Filter Sock by Syflico

It should be noted that some products may have restrictions regarding use. For details please contact Don Malott at (517) 322-5687.

This document is disseminated as an element of MDOT's technical transfer program. It is intended primarily as a means for timely transfer of technical information to those MDOT technologists engaged in transportation design, construction, maintenance, operation, and program development. Suggestions or questions from district or central office technologists concerning MATES subjects are invited and should be directed to M&T's Technology Transfer Unit.

Technology Transfer Unit
Materials and Technology Division
Michigan DOT
P.O. Box 30049
Lansing, Michigan 48909
Telephone (517) 322-1637