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68th Annual Meeting

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ABSTRACT

Crushed aggregate containing approximately 8% by weight of soft coal was utilized in the construction of asphaltic concrete pavements on 23 km of secondary and primary roadways. Within 5 months after construction, surface distress in the form of ravelling, pitting, and localized potholing occurred along and outside the wheel paths. The presence of coal in the aggregate had been identified during the quarrying and crushing stages. Normal and 24-hour soaked Marshall Stability tests were undertaken to evaluate the quality of the crushed aggregate. Retained stabilities of 20 to 69% were obtained using samples obtained from the crushing plant and dryer of the asphalt plant, respectively. It was decided to utilize the aggregate on the basis of the higher stability obtained from the asphalt plant processed material. This decision was also influenced by a contract deficiency pertaining to the 'acceptable' amount of deleterious material. For production asphaltic concrete, a 70% retained stability was chosen as a minimum requirement for an acceptable mix.

During the first 6 km of paving, lower than the target retained stability resulted in the contaminated aggregate being blended with 20% of clean aggregate. This blend resulted in 80 to 90% retained stability. Despite this, all roadways suffered pavement distress. To stop the progressive pavement deterioration a fog seal was applied to the secondary roadways with a subsequent single surface seal applied to all roadways in 1985. Since then, no further pavement distresses have been reported and the roadways are performing well.

INTRODUCTION

Mineral aggregates constitute 88% to 96% by weight, or approximately 80% by volume of an asphaltic concrete pavement. As a major component, aggregates, therefore, directly influence the structural integrity and durability of the pavement structure. To ensure that performance and service life of a pavement are not affected prematurely, high quality aggregates are generally preferred in the manufacture of asphaltic concrete mixes. Gradation, shape, strength, toughness, durability, hydrophobic characteristics and cleanliness are the quality attributes of aggregates that govern their behaviour and hence the ultimate pavement performance under load and non-load associated environments.

It is generally recognized by highway agencies, worldwide, that aggregates for asphaltic concrete mixes should be clean. Cleanliness of an aggregate is determined, in general, by the presence or absence of deleterious or harmful materials. The overall quality ranking of an aggregate is often influenced by the types and amounts of deleterious material within the aggregate matrix, with high quality aggregates having none to negligible amounts of deleterious materials.

Materials considered to be deleterious include clay, clay lumps, soft shale, lignite, coal, mica, shells, organic matter, vegetable matter, and roots. Some highway agencies provide percentage limitations on the amounts of these materials. Others, state their objection to deleterious materials, qualitatively, while others consider that their requirements for the quality attributes of strength, toughness, and durability would limit the amount of deleterious material. The types of deleterious materials and their percentage limitations in coarse and fine aggregates considered by fifty highway agencies in North America are reported by Chastain and Burke (1).

In Alberta, the majority of the aggregates used in asphaltic mixes in the Provincial highway system is obtained from naturally occurring gravel and sand sources. In addition to the impurities such as clay, clay lumps and organic matter, coal is frequently encountered within gravel aggregates sources.

When coal is encountered during the gravel prospecting stage, the source is considered unsuitable if the amount of coal is significant and if its disposition is such that quarrying of the deposit would not eliminate this material.

In the situation where the coal is discovered during quarrying, stripping and removal of the coal is undertaken or the deposit worked in such a manner to avoid aggregate contamination. This situation is generally not the norm since most sources are pretested prior to large scale use. Where selective quarrying is undertaken, it is generally impossible to eliminate all coal from any known contaminated deposit. In such cases, the amount of coal acceptable is based on visual observations of the colour of the total aggregate rather than by actual testing. Generally, the percentage acceptable from visual observation may not exceed about 1% by weight of the total aggregates.

While it is well established that coal is highly undesirable in aggregates for portland cement concrete, coal in asphaltic concrete aggregates, however, is not treated with the same degree of concern. According to Woods (2), the ASTM specifications, by not including a section on deleterious materials, recognize that small amounts of deleterious materials are not as harmful to bituminous concrete as they are to portland cement concrete.

Very little published work is reported in the literature on the influence of coal on asphaltic concrete behaviour. One of the reasons for this scarcity of information on this topic is that this material is restricted to a trace in aggregate production, and hence may not have created a situation warranting any special study.

The purpose of this paper is to present a case-study of the performance of asphaltic concrete pavements along two secondary roadways and one primary highway constructed with coal contaminated aggregate containing a significant percentage of coal.

PROJECT BACKGROUND

Under an Alberta Transportation (now known as Alberta Transportation and Utilities) contract, the scope of work included the construction of approximately 23 km of asphaltic concrete pavement construction along three designated roadways consisting of one primary (Hwy. 28:04) and two secondary roadways (SR 827:02 and SR 644:04). The location of these roadways is shown on Figure 1.

Structural pavement design of the three roadways was based, with slight modifications, on the Asphalt Institute Method of Design (3). A California Bearing Ratio of 4% for the subgrade soil and a 20 year roadway design life were common to the design of the roadways. Other design parameters consisted of an Average Annual Daily Traffic (AADT) of 3,300 vehicles per day and Design Traffic Number (DTN) of 334 for Hwy 28:04) with AADT of 700, DTN of 56 for the SR 827 overlay, and AADT of 250 and DTN of 23 for SR 644:02.

Hwy. 28:04

This project was a realignment of Hwy. 28:04 in the vicinity of Junction Hwy. 28:04 and SR 827:02 to facilitate the construction of an at-grade railroad separation. The length of the realignment was approximately 1.4 km and required embankment, base and surfacing constructions.

This roadway, designed to accommodate two-way traffic, consisted of a 13.8 m finished pavement width and a 400 mm thick structural pavement. The pavement thickness consisted of 300 mm granular base course and 100 mm asphaltic concrete pavement.

SR 827:02

This project involved new construction (embankment, base and surfacing), embankment only, and asphaltic concrete pavement overlay.

As a two-lane secondary roadway, this road was designed with a 9 m finished pavement width and a 330 mm structural pavement thickness consisting of 230 mm granular base and 100 mm asphaltic concrete pavement.

The asphaltic concrete overlay construction covered a distance of about 15 km beyond the limit of the new construction and extended into the Town of Thorhild. The existing pavement was constructed in 1980-1981 and consisted of 175 mm soil cement base and 50 mm asphaltic stabilized base course. The designed overlay consisted of 60 mm asphaltic concrete pavement.

SR 644:02

Construction of this project roadway consisted of subgrade preparation, base course and asphaltic concrete pavement construction over a total project length of approximately 4 km. Designed to accommodate two-way traffic, this roadway was constructed with a finished width of 9 m and a 350 mm structural pavement thickness. This pavement thickness consisted of 230 mm granular base and 120 mm asphaltic concrete pavement.

CONSTRUCTION AGGREGATES

Location

The aggregates utilized in granular base and asphaltic concrete pavement constructions were obtained from a naturally occurring gravel aggregate source. This source, situated along the North Saskatchewan River, was located approximately 38 km from the Jct. SR 827 and Hwy. 28:04. The pit location in relation to the project roadways is shown on Figure 1.

Prior to the gravel crushing operations an inspection was made of the pit site. At the time of the inspection, preparation of the crushing plants and stockpile sites was in progress. The following observations were made:

1. The pit site had been extensively worked and appeared to be depleted.
2. Pit rehabilitation had not been carried out following excavation and crushing. A number of waste stockpiles had been randomly left creating the appearance of an abandoned pit.

3. The area identified for quarrying was a narrow bank of high ground at the east fringe of the pit area. The workable gravel seam was 2 to 4 m in thickness and was located below 6 to 8 m of clay overburden. Medium to coarse sand existed below the gravel. Figure 2 shows a section of the workable pit area.

GEOLOGICAL CONSIDERATIONS

Briefly, the aggregate source forms part of the Saskatchewan sands and gravels - sand and gravel deposited in preglacial valleys (as valley till in terraces) before the onset of the Quaternary glaciation. Generally, the composition of the Saskatchewan gravels consist of primarily quartzitic rock with minor amounts of chert, clay ironstone and coal. Coal is derived from the local bedrock (Edmonton Formation) through bedrock incision by the preglacial rivers. Additional information of the geological setting and characteristics of the Saskatchewan sands and gravels can be obtained from Shaw and Kellerhals (4), Kathol and McPherson (5), and Edwards, Hudson and Scafe (6).

SUPPLY

The supplemental provisions of the contract required the aggregates to be supplied from a source of the Contractor's choice. The materials supplied were to satisfy the gradation specifications for Designation 1 Class 16 and Designation 2 Class 40 materials (Figure 3). The Designation 1 Class 16 material was to be used in both granular base course and asphaltic concrete pavement constructions.

In terms of the quality attributes of strength, durability and soundness, the General and Construction Specifications required under Specification 5.1, Subclause 5.1.02.2 - Gradation Requirements - the following:

> "The crushed aggregate shall be composed of sound, hard and durable particles of sand, gravel and rock with all material up to and including 300 mm crushed, and shall be free from elongated particles, injurious quantities of flaky particles, soft shales, organic matter, clay lumps, and other foreign matter.."

PRETESTING

Since the aggregate source was to be the Contractor's choice, no pretesting of the source was done by the Department. Information regarding the characteristics of the source was therefore unavailable until actual quarrying and crushing had commenced. However, according to post-construction information, this source had been tested by the Department some 20 years ago. At that time, it was noted that the source consisted of fine to coarse gravel deposits with numerous sand seams. Testing had also been undertaken by an independent testing laboratory. According to a departmental appraisal of the testing laboratory's report, it appeared that the quality attributes of the aggregate had not been well addressed leaving some reservations of its quality. The appraisal, nevertheless, considered that the source material may be suitable for use in highway construction. No mention was made by either the Department or the independent laboratory of the presence of coal within the source.

CRUSHING

Crushing

Crushing of pitrun gravel to produce Designation 1 Class 16 material for asphaltic concrete and top lift granular base course constructions began on September 17, 1983. Approximately 2000 tonnes of material had been crushed and stockpiled by the Supplier on September 20, 1983, when quality control monitoring was officially initiated on site. The material was produced as an "all-in" aggregate. The production of an "all-in" aggregate was chosen by the Supplier instead of splitting and recombination of the coarse and fine fractions.

The stockpiled aggregate was inspected on September 20, 1983, following a request by the Contractor and Supplier for gradation checks to determine whether the crusher settings were satisfactory for producing the desired crushed aggregate.

The inspection of the aggregate stockpile revealed the presence of finely divided particles of coal which gave the stockpile a very dark appearance resembling from a distance an oilbound aggregate stockpile. Figure 4 shows the appearance of the Designation 1 Class 16 material when laid as base course on the roadway.

Following the inspection of the aggregate stockpile an examination of the pit was made. Five thin coal seams 75 to 150 mm in thickness were observed to be interspersed within the 2 to 4 m workable gravel face. On close examination, the coal was soft and could be readily disintegrated between the fingers to dust size particles. One seam in particular was brown in color and contained leafy vegetative matter. It was assumed that this seam was in a transitionary stage of coalification. The disposition of the five coal seams made it practically impossible to avoid contamination of the pitrun gravel during excavation.

On-site discussions were held immediately with the Contractor and Supplier expressing the unsuitability of the pit to produce asphaltic concrete aggregate.

A sample of material was taken from the stockpile and tested for gradation and percent fractures. The presence of coal with in aggregate was also confirmed during washing of the aggregate. Both the gradation and percent fractures failed to meet the specification requirements.

Six additional samples were taken from the crusher discharge during production on September 21, 1983. These samples also failed to meet the gradation specification requirements and were stockpiled separately. The crusher was finally adjusted to produce the desired aggregate at around 7:30 P.M. that day. Two samples were taken during the night shift and both satisfied the specification requirements in terms of gradation and fractures. Between September 22 and 25, when operations were temporarily halted, material produced was slightly coarser than the specification requirements between the 315 and 80 (metric) sieves. This deviation from the specifications was consistent and was considered not to be critical.

The presence of coals in the aggregate resulted in material crushed between September 20 and 21 to be submitted to the Transportation Laboratory for analysis to determine the aggregate's suitability for use in asphaltic concrete pavement construction. The suitability of the aggregate was assessed from Marshall stability tests done on both normal (30 to 40 minute soaked) and 24 hour soaked specimens. The criterion used to assess the suitability of the mix and hence the aggregate suitability was that the retained stability (percentage of soaked to normal stability) should be at least 70%. The soaked stability test, also known as the Marshall Immersion Test, measures the change in stability resulting from the action of water on compacted bituminous mixes. The test is done on samples prepared with the same asphalt content, gradation and number of blows as the Marshall specimen tested in the normal manner.

Preconstruction Aggregate Evaluation

Using a batch split (aggregate tested as submitted), two sets of three Marshall briquettes were made with 6 and 6.6% asphalt by weight of dry aggregate. The briquettes were formed using 50 blows on each of the two faces of a specimen. Both normal and soaked stability tests were carried out. For the soaked tests, the specimens were tested after 18 hours rather than 24 hours. This was done to facilitate an early assessment of test results. Retained stabilities of 20 and 28% were obtained for the specimens made with 6 and 6.6% asphalt, respectively. Since these values were considerably lower than the 70% considered acceptable for high quality asphaltic concrete, the mix was considered unacceptable. According to the Materials Testing Laboratory, the low retained stability might have been influenced by the gradation of the aggregate. This gradation was slightly finer than the specification requirements. In addition to the stability testing, testing was carried out to determine the percentage coal in the aggregate. Using a floatation method, the percentage was determined to be 0.89% by weight of total aggregate. However, by burning at 800°F for 14 hours, 8% coal by weight was obtained. In terms of the physical appearance of the aggregate, 8% was considered to be a far more realistic value.

As a result of the low retained stability, a meeting was held with the Contractor and Supplier on September 25 during the night shift crushing. It was agreed at that time that further crushing would be halted pending the results of further laboratory investigation.

Further testing was undertaken on samples taken from the crusher discharge between September 21 and 25, 1983. A three point Marshall mix design was carried out on aggregate batch samples. The retained stability was 34% despite the gradation of the material satisyfying the specification requirements.

On account of these low results it was decided that the aggregate was unacceptable for use in asphaltic concrete pavement construction. Both the Contractor and Supplier were advised of the decision. However, at a further meeting between the Contractor and representatives of the Department, it was agreed to further assess the mix characteristics on aggregate processed through the dryer drum at normal operating temperature. This was done to verify the contractor's opinion that the coals would burn off from the aggregate once heated to mixing temperature.

For the stability tests on plant processed aggregate, it was decided to investigate the suitability of Designation 1 Class 12.5 aggregate in addition to the Designation 1 Class 16 aggregate.

Two sets of 12 briquettes of the Designation 1 Class 12.5 and Designation 1 Class 16 aggregate were tested for normal and soaked stabilities. Retained stabilities of 55 and 69% were obtained, respectively. Although these values were less than the 70% criterion, it was decided to allow the use of Designation 1 Class 16 aggregate. It is of interest to note that coal was still observed in the aggregate after processing through the dryer drum. No checks were made on this percentage coal.

To ensure that the stabilities were consistently high during actual production, it was decided to continue Marshall stability testing on field formed briquettes. The Contractor and Supplier were both notified that should the retained stabilities drop significantly lower than 70%, the use of the contaminated aggregate would be stopped. This decision was agreeable to both the Contractor and Supplier. In fact, they had suggested prior to the plant trials an alternative plan which involved the use of a percentage of clean aggregate from another of the Supplier's sources.

Production of Designation 1 Class 16 material from the contaminated source resumed on October 7, 1983. The Supplier continued to produce and "all-in" aggregate satisfying the gradation and fracture specifications. The weekly average gradation up to the completion of crushing is shown on Figure 3.

ASPHALTIC CONCRETE PAVEMENT CONSTRUCTION

QUALITY CONTROL CHARACTERISTICS

SR 827:02

Asphaltic concrete pavement construction commenced on October 12,1983, starting from km 0.937 towards km 16.137 (Figure 1). The "all-in" coal contaminated aggregate was used with 6.6% of 200-300 penetration grade asphalt cement to initiate paving. The 200-300 asphalt cement grade was also utilized in the paving of SR 644:02. Asphaltic concrete mixes for both of these roadways were based on the characteristics of a 50 blow Marshall stability design satisfying, in general, the Asphalt Institute Marshall Stability Design Criteria.

During plant production on October 12, 1983, eight field formed briquettes were made for stability evaluation. An average retained stability of 55% was obtained with the normal stability averaging 5201 N and the gradation satisfying the specification requirements.

On the basis of the low retained stability it was decided to pursue the option of blending the contaminated aggregate with aggregate from the Supplier's alternate source. A mix of 20% by weight of clean aggregate and 80% of contaminated aggregate was found to satisfy the aggregate gradation requirements.

The use of this blended aggregate to continue paving of this project from km 6.6 resumed on October 31, following the completion of paving of Hwy. 28:04 and SR 644:02. These latter projects were given priority since subgrade and base course constructions had been completed while paving was in progress on SR 827:02. Paving of SR 827:02 was finally completed on November 6, 1983.

Quality control monitoring of the mix characteristics and field compaction resulted in 25 field formed Marshall briquettes and 65 field cores. The percentage compaction achieved varied from 91 to 98% of the field formed Marshall density with an overall average compaction of 95%. Field air voids ranged from 8 to 11% with an overall average of 10% while mix asphalt content averaged 6.2% with a range from 5.7 to 6.8% determined by the nuclear gauge. A similar range of asphalt content was determined from bulk and totalizer plant checks. Aggregate gradations were found to satisfy the job mix formula, generally.

Hwy. 28:04

The asphaltic concrete mix utilized in the paving of this project roadway consisted of the blended aggregate and 5.7% of 150-200 asphalt cement. This design was based on a 75 blow Marshall stability simulating the heavy traffic category criteria. Characteristics of the design mix were as follows:

Stability	8200 N
Asphalt Content	5.7%
Density	2329 kg/m^3
Air Voids	4.0%
Voids in Mineral Aggregate	15.3%
Voids Filled with Asphalt	73%
Flow	2 mm
Retained Stability	79%

Mix reaction to kneading compaction was medium.

Pavement construction commenced on October 17 and was completed on October 20, 1983. During this period 20 briquettes were made for stability evaluation. Six of these made on October 17, 1983 gave an average retained stability of 82% with an average normal stability of 9154 N. The remaining fourteen briquettes were made on October 19, 1983. Three gave an average retained stability of 74% and average normal stability of 8725 N with stability values ranging from 7562 to 10231 N.

Since the retained stabilities consistently exceeded the minimum criterion, the mix was considered acceptable for use from a laboratory analysis viewpoint and further testing was discontinued.

A summary of the quality control monitoring information from thirty field formed Marshall briquettes and twenty-seven field cores showed the field compaction to range from 91 to 97% with an overall average of 93%. Field air voids ranged from 6 to 13% with an overall average of 10% while mix asphalt content varied from 5.5 to 6.1% with an average of 5.6%. A similar range of asphalt content was determined from bulk and totalizer plant checks.

SR 644:02

Paving of this 4 km stretch of roadway was undertaken following completion of Hwy. 28:04. The mix contained the same aggregate combination as that used on Hwy. 28:04 with the exception that 200-300 asphalt cement was used with an optimum asphalt content of 6%. Roadway paving commenced on October 22 and was completed on October 28, 1983.

No retained stability checks were done, rather field formed briquettes were made for reference density and air voids determinations for compliance with mix design characteristics, and evaluation and comparision of field compaction control characteristics. A summary of the mix characteristics and field compaction determined from fifteen field formed briquettes and thirty-six field cores showed the following:

(a) Percentage compaction ranging from 91 to 97% of field formed Marshall briquette density with an overall average of 95%.

(b) Field voids ranging from 8 to 13% with an overall average of 9%.

(c) Mix asphalt content ranging from 5.6 to 6.3 % with an overall average of 5.9%. A similar range of asphalt content was determined from bulk and totalizer plant checks.

MIX LAYDOWN CHARACTERISTICS

During mix placement and rolling a few observations were made which appeared to be somewhat unusual when compared with observations of mixes made with uncontaminated aggregates.

1. Difficulty in obtaining consistently high densities despite adequate compaction equipment and varying techniques used in mix rolling.

   Both vibratory and pneumatic tire rollers were employed on the project. The best combination for achieving reasonably good compaction on all projects consisted of two breakdown passes with vibratory on the forward roll and static on the return roll for each pass utilizing a Dynapac CC 50A roller. Three breakdown passes with vibratory on both the forward and return rolls were found to be too severe and resulted in fracturing the mat. While several factors can influence compaction, it appeared, based on visual observations, that mix material characteristics was a major influencing factor since asphalt content and aggregate gradation were in compliance with specification requirements. In consideration of the influence of ambient air temperature during mix laydown a mean maximum of 10°C and a mean low of 0.4°C with an overall mean of 4.7°C were recorded over the duration of construction. Temperature was not considered to be an influencing factor since late fall paving is usually undertaken at temperatures up to about -5°C without influencing pavement performance. Since the asphaltic concrete specifications do not stipulate a cut off temperature, construction during fall is often undertaken at the discretion of the Project and District Engineers. The guidelines often used for late fall construction are that paving is not undertaken during snowfall and an acceptable level of compaction is achieved. It is the writer's experience that 95% compaction is readily achieved during paving in ambient air temperature of -5°C.

2. "Picking-up" and excessive steaming of mix during breakdown rolling.

   Frequent mix pick up by the rollers occurred despite clean and properly wetted wheels. This was also observed to a lesser extent during pneumatic tire intermediate rolling.

3. Tendency of mix to hairline crack during breakdown rolling.

   Intermediate rolling by a pneumatic tire roller was found to seal these cracks.

4. Quick "set-up" of mix under breakdown rolling.

POST CONSTRUCTION ROADWAY EVALUATION

ROADWAY OBSERVATIONS

On April 6, 1984, approximately 5 months following the completion of roadway paving, the Area Maintenance Foreman reported the observation of cracks within the pavement surface along Hwy. 28:04. An inspection of this roadway undertaken the same day revealed crescent shaped tearing and slippage cracks within the asphaltic concrete top lift at one location and impending pavement slippage at other locations west of the at-grade railway crossing. The slippage and potential pavement slippage cracks were concentrated on the high side of the horizontal curve and covered a distance of about 200 metres. These cracks were subsequently reasoned to have occurred due to the lack of application of a tack coat between lifts during asphaltic concrete pavement laydown.

Pavement cracks were also noticeable east of the railroad tracks where the roadway was along tangent or normal crown pavement sections. These cracks bore some resemblance to fracture cracks in brittle materials and can perhaps be best classified as random cracks. These cracks were associated with high porosity areas as evidenced from the moist and open texture of the pavement surface at these locations. No pavement slippage had occurred on this side of the tracks nor were there any signs that this type of pavement distress was pending. It is of interest to note that no tack coat was used between asphaltic pavement lifts.

In addition to the cracking and pavement slippage phenomena, other surface distress manifestations became readily apparent during the site inspection. These consisted of loss of fine aggregates, ravelling and pitting of the pavement surface.

The loss of fine aggregate was evident throughout the entire roadway length. This loss gave the pavement a very coarse textured appearance which was very pronounced along wheel paths and at the intersection of Hwy. 28:04 and SR 827:02. The appearance of the pavement resulting from this loss of fine aggregate is illustrated by Figure 5.

Ravelling of the mix was evident at the tapers at the beginning and end of the paved section of roadway. At these locations where the new roadway adjoins the existing, the mat is generally very thin. Although the loss of aggregate at these locations was anticipated, the extent to which this occurred was unusual when comparisons were made with similarly paved roadways with varying pavement lives. It was concluded, based on the visual observations, that the loss of aggregate was definitely too severe within the short period of pavement life.

The loss of coarse aggregate particles from the pavement surface giving the mat a pitted or pock-marked appearance was also quite evident. This distress manifestation was distinct from the loss of fine aggregate and from the ravelling that occurred at the tapers. On close visual and surficial examination of the pavement it was found that some of the coarse aggregate particles could be readily removed with a penknife using moderate pressure. Some of these particles were associated with poor aggregates such as chert and clay ironstone, typically found within the Saskatchewan gravels. Figure 6 depicts the pitted or pock-marked appearance of the pavement surface.

SR 827:02

This roadway was also found to exhibit the same surface distress manifestations that occurred on Hwy. 28:04 with the exception that pavement tearing and slippage cracks were absent. In contrast to Hwy. 28:04, the pavement overlay was constructed in one lift and on an existing pavement surface that was tacked prior to asphalt laydown.

In addition to ravelling at the tapers, there was ravelling to the full depth of the new mat at several locations resulting in the formation of potholes within the pavement. Longitudinal streaking of the surface was also observed within the 0.8 km stretch north of Jct. Hwy. 28:04 and SR 827:02.

In the Town of Thorhild the loss of fine aggregate was extremely severe resulting in a very rough textured pavement surface as shown by Figure 7. Random pavement cracks, similar to those observed on Hwy. 28:04, were also observed at isolated sections.

SR 644:02

With the exception of tearing and slippage cracks, potholing and streaking, all other surface distress manifestations that occurred on Hwy 28:04 and SR 827:02 were readily noticeable along the entire paved length of SR 644:02. The degree of severity of the distresses was, however, not as pronounced and may have been retarded owing to the lower volume of traffic that uses this roadway. It is of interest to note also that no tack coat was utilized between lifts of asphaltic concrete pavement.

REMEDIAL MEASURES

On May 7, 1984, a further inspection of the roadway was undertaken by the Department's Surfacing Consultant. Based on his observations, it was recommended that SR 827:02 and SR 644:02 should be fog sealed immediately with an SS-1 emulsion at an effluent rate of 0.5 kg/m^2. Further, it was recommended that all roadways should be scheduled for seal coating in the 1985 construction program.

Fog sealing of the secondary roadways was done in June 1984 with the application of the single surface treatment to all roadways during May-June 1985. Prior to the application of the surface seal coat to Hwy. 28:04, the slipped areas were removed and repaved. Since the application of the seal coat no further surface distress has been reported.

AGGREGATE EVALUATION

In comparing the performance of the project roadways over the 5 month period with similarly paved roadways in service from 1 to 10 years and constructed with coal free aggregate, it was clearly obvious that the surface distress manifestations that occurred on the project roadways resulted from mix aggregate characteristics.

Considering the possible variables that could have contributed to the types of distress observed, it was felt that the presence of the coal impurity was a significant contributor, if not, the primary cause of poor pavement durability.

As a first step in this evaluation an X-ray diffraction analysis of the contaminated aggregate was undertaken. This analysis was even done prior to the reported distresses and site inspection since the presence of this impurity aroused curiosity during the crushing and preconstruction evaluation stages. Later, a coal petrographic analysis was done to determine the ranking of the coal since it was felt that the soft nature of the coal was influenced by a high percentage of organic matter content.

X-ray Diffraction Analysis

X-ray diffraction analysis was conducted on the minus 125 micron and minus 2 micron particle sizes of the coal contaminated Designation 1 Class 16 aggregate. This analysis reported on April 4, 1984, showed the minus 125 micron particles to comprise mainly of silt sizes with quartz being the dominant mineral and some feldspar, illite, and christobalite. The minus 2 micron size showed clay sizes to constitute a small part of the total sample. The minerals present were mainly montmorillonite with some illite, koalinite and quartz. As an overall assessment, it was determined that there was nothing unusual about the presence of the minerals noted. The presence of bentonite, presumed prior to the analysis, was not indicated. Bentonite was presumed to possibly account for the low retained stabilities that were obtained from laboratory testing before and during pavement construction.

Coal Petrography

A petrographic analysis of the coal containment was undertaken to ascertain its ranking. Briefly, the petrographic composition of coal can be expressed terms of macerals and microlithotypes. Macerals are the basic constituents of coal and are analogous to the minerals of organic rocks. Microlithotypes are distinct assemblages of macerals and may be considered equivalent to rock type of inorganic petrology (7).

Ranking of the coal is obtained by measurement of reflectance. The technique is based on the fact that as the rank of the coal increases so does its reflectance. It is a precise method of determining rank and has the advantage that it can be done on one component, namely vitrinite. Vitrinite is the coalified remains of a variety of plant tissues with a large contribution from wood and bark. It is normally the most abundant constituent of coal (7).

The results of the petrographic analysis are summarized in Figure 8 as a plot of frequency versus reflectance. This data was obtained from a 35 point vitrinite analysis. As shown, the reflectance ranges from a minimum of 0.135 to a maximum of 0.475 with a mean of 0.239. On the basis of these results the coal can be ranked as "peat" according to the German and North American (ASTM) classifications. A characteristic feature of the rank of this coal is its bed moisture which is about 75%.

DISCUSSION

In an asphalt-aggregate mix containing coal, the coal will tend to coat the asphalt film first and hence result in reduced bonding between the asphalt and aggregate. Poor aggregate-asphalt bonding would directly influence mix strength and durability. Hence, the mix would be more susceptible to the influence of moisture and disintegration by weathering.

Further field evidence of the influence of coals on mix behaviour was obtained from research aimed at exploring the possibility of making an improved binder for bituminous pavements by dispersing coal in distilled coal tars and oils (8).

Thirteen test sections covering a distance of 16 km and a similar number of control sections covering a distance of 18 km were constructed using coal-modified, coal tar binder, and standard asphaltic binder, respectively. The control sections were constructed near or adjacent to the test sections.

The following is a summary of some of the observations made from six test sections during the first 2 years of pavement construction.

1. About three months after construction excessive ravelling and wearing away of the surface course were occurring in two of the test sections. The wear was progressive and patching had to be done at an early stage. At several places in urban sections the entire thickness of mix was worn through along wheel paths.
2. Ravelling and loss of fine aggregate resulted in a rough textured pavement surface.
3. The experimental mix lacked flexibility. Edge cracking developed rapidly and old surface and base failures soon reflected through the mix.
4. The degree of pavement deterioration was less on roadways that were subjected to low volumes of traffic (less than 100 vehicles per day).

CONCLUSIONS

On the basis of observations made during and after construction of the project roadways and observations by other, it would seem appropriate to conclude the following:

1. Surface deterioration in the form of ravelling, loss of fine and coarse aggregates, and cracking can be expected from mixes containing coal.
2. The degree of severity of deterioration of the pavement surface would depend on the type and amount of coal, and on the volume of traffic.

3. The application of a surface seal coat immediately following paving would aid considerably in preventing deterioration of the pavement surface.

RECOMMENDATIONS

Further research is necessary to determine the amount of coal that would be acceptable in an asphaltic concrete mix without resulting in serious pavement deterioration. This work would also provide some guidelines for the acceptance and rejection of source materials. At the moment it appears that the decision on whether to use or not to use a coal contaminated source is subjective or based on the results of Marshall Immersion tests. Although the Marshall test can give some indication of the presence of deleterious material, this test does not provide information on the likely performance of the pavement structure due to weathering. Freeze-thaw and some form of abrasion testing would seem to be warranted for judging long term performance.

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FIGURE CAPTIONS

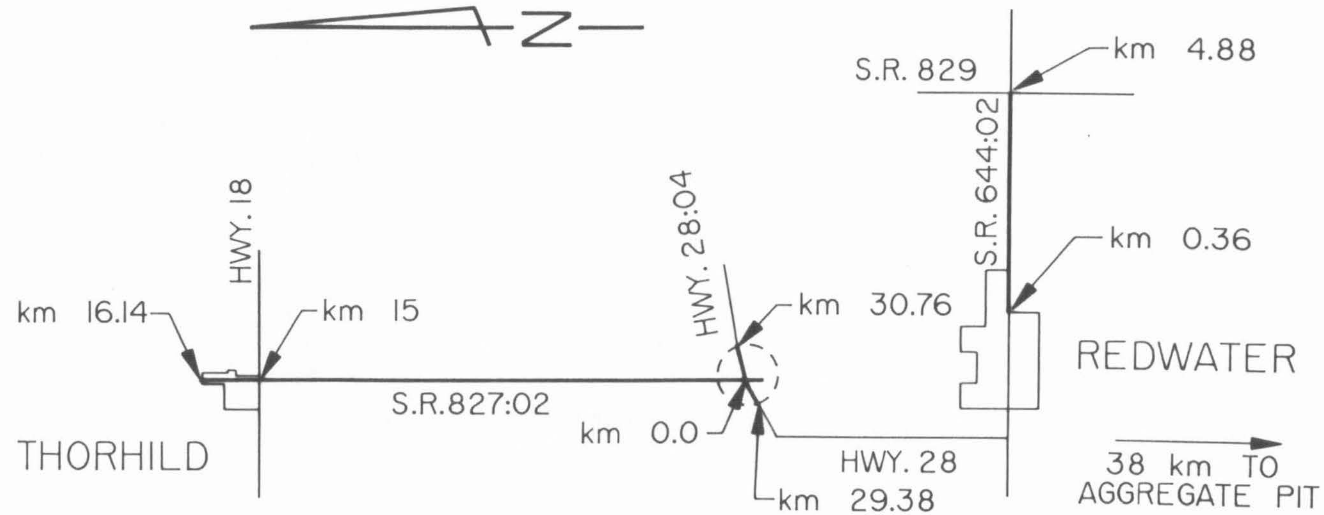

Figure 1: Location of Project Roadways

Figure 2: Section of Workable Pit Area

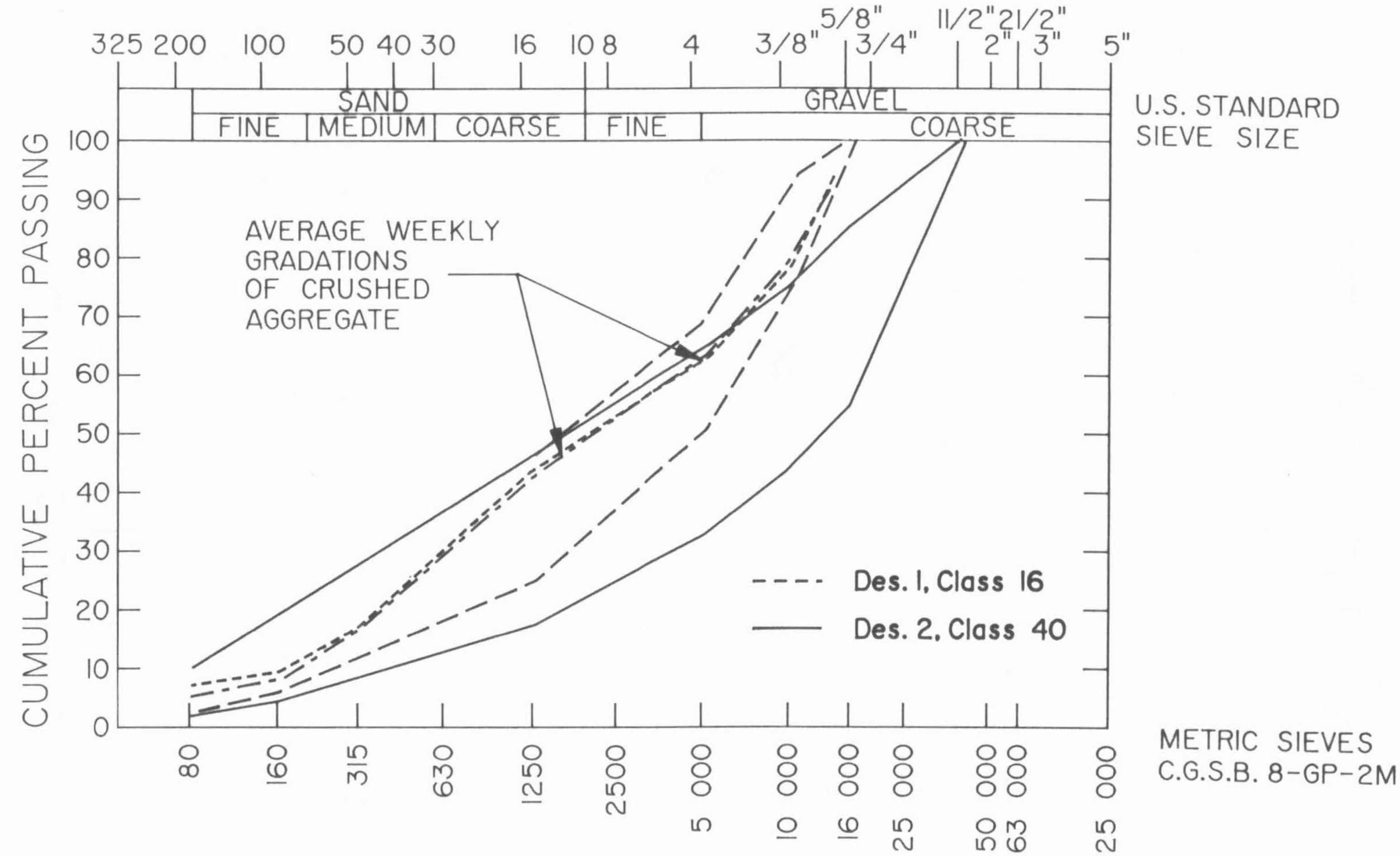

Figure 3: Aggregate Gradation Specifications

Figure 4: Appearance of Designation 1 Class 16 Material as Base Course

Figure 5: Pavement Surface Texture Due to Loss of Fine Aggregate

Figure 6: Pitted or Pock-marked AppearanceDue to Coarse Aggregate Loss

Figure 7: Severe Ravelling

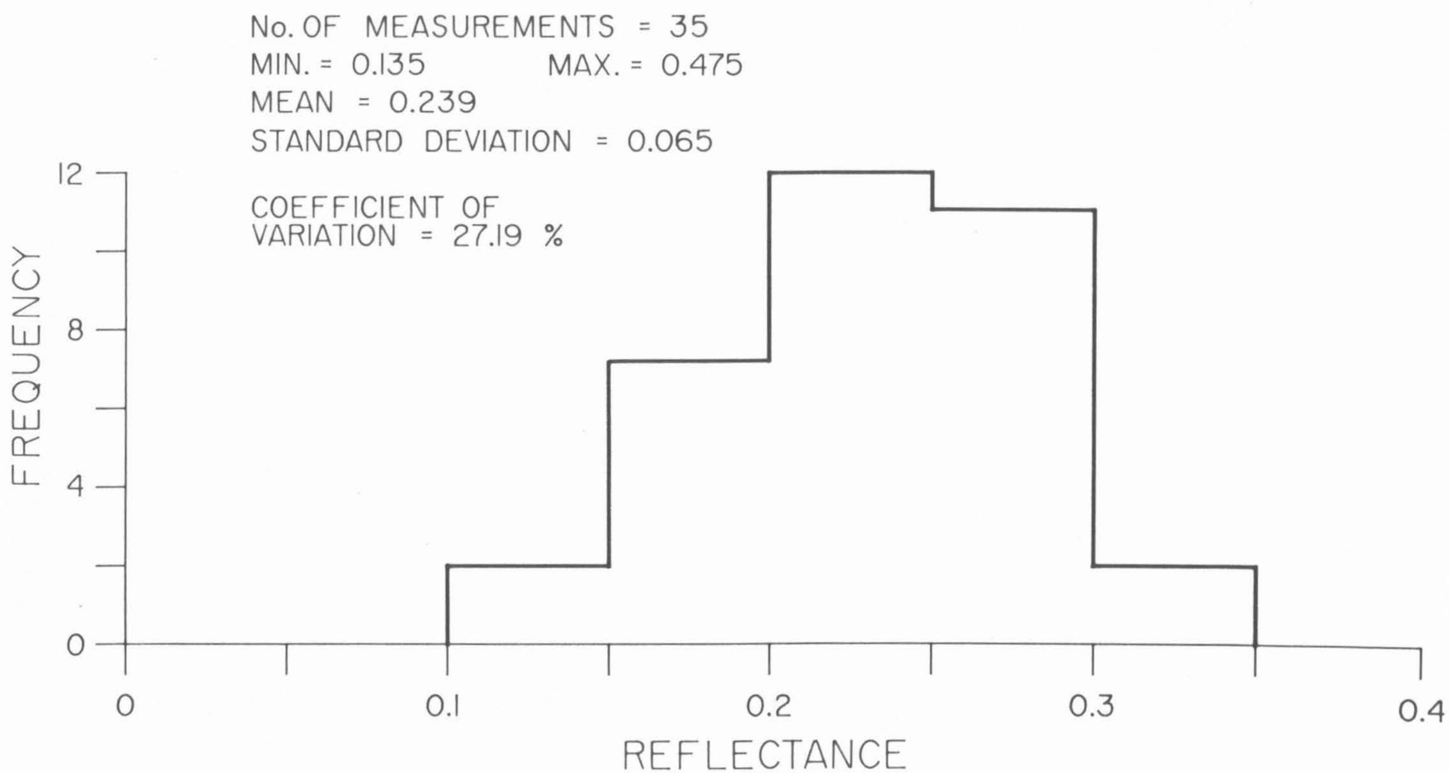

Figure 8: Reflective Diagram - Coal Petrography