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Difficulties in Choosing Sustainable Materials

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ABSTRACT

Budgets and the choice of materials often exist in conflict. With ever shrinking revenues and budgets the choice of durable, usually more expensive materials becomes difficult. Cost benefit analysis results often show the higher expense of durable materials at the beginning of a project is less expensive in the long term. However, because budgets are small and the need for improvements is high the choice for the higher quality product gets pushed aside in lieu of doing more projects now.

Other influences on this material selection include local availability and the characteristics of natural resources. The quality of aggregates varies between formations and geographic locations. The use of the uncrushed gravels in concrete and hot mix asphalt has given way to crushed materials. This has lead to the use of crushed limestone because the particle size of many natural gravel deposits is not large enough to crush and meet the needed coarse aggregate gradation.

BACKGROUND ON HIGHWAY SYSTEM IN THE UNITED STATES

In the United States the infrastructure projects are split between the Federal Government, State Governments and Local Agencies. The United States is separated into 50 individual states that are very similar and yet slightly unique in their own way. Some states are divided into counties and some into parishes. Illinois for example is divided into 102 counties.

There are several different types of roadway classifications based on their intended use and how many vehicles use them. In Illinois these types are called Interstate, US Route, State Route, County Highway and Township Road. The Interstates function as the word implies, allowing vehicles the ability to travel at the highest speeds and highest level of service between states. Some of these interstates go for long distances and cross many states, some cross the entire country. In the Chicago area and other large metropolitan areas, however, some of the individual interstates such as I-355 do not cross state borders but connect one interstate with another.

The roadways with a US Route designation are similar to interstates in that they cross multiple states but at a lower level of service and speed. Travelers on these routes are subject to flow interruptions such as stop lights and or stop signs in the various cities, towns and villages they connect. These routes may be multi-lane or single lane for each direction and

are typically striped with white edge of pavement markings and yellow centerline markings giving directions as to when it is and isn't all right to pass a slower vehicle.

State Routes do not cross the state borders and keep the same designations. For example Illinois Rte 17 on the east side of Illinois changes its designation to Indiana Rte 2 when it crosses the border. These roadways like the US Routes can be subject to numerous flow interruptions. The pavements of these roadways are typically the same width as that found on a US Route but may not have as wide of a shoulder. The pavement markings are relatively the same.

County Highways do not cross the border of its governing body. These routes can be narrower than the roadways discussed above but will still have similar pavement markings.

The Township Roads typically have much less traffic than the routes discussed above. Most are made of lesser materials and the pavement structures are thinner. In some cases these roads are no more than a berm with an aggregate top. There are typically no pavement markings.

Sustainable Materials

The individual States use large quantities of materials to maintain and improve the serviceability of the existing roadways as well as construction of new roadways where needed. A material such as wood is sustainable as it grows back, as long as the last tree or acorn is not used. The definition of sustainability, according to Merriam-Webster online dictionary (www.merriam-webster.com/dictionary) is "2a: of, relating to, or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged". Does this mean a material can never be used up? Coal, Limestone and other rock is plentiful in the United States. This does not mean that there will never be shortages of aggregate, cement, lime and fly ash, which are all products of various processes applied to raw coal and limestone. Shortages exist now, but are typically temporary during the peak use of these materials, typically during the summer construction season. A foreseeable problem in the future may be the current and future land uses above the coal and limestone deposits. The Illinois Valley area, in particular the area between Morris, Illinois and Peoria, Illinois is blessed with substantial deposits of coal, limestone, sand and gravel. The owners of these deposits are in a strong business position if they own the surface acreage necessary for future mining. Several companies have had to cease mining operations because they exhausted the deposit within their property limits. With today's dust control and noise standards towns that have developed around mining operations have limited the horizontal development of the mining operation.

With the effort to reduce the use of raw materials the Illinois Department of Transportation as well as most other state DOT's have put an emphasis on using recycled materials. Hot Mix Asphalt, HMA, pavements allow varying amounts of recycled material in the mixture depending on its end use. A typical HMA mixture allows up to 25% recycled asphalt pavement, RAP, which is the milling of a previous HMA pavement.

The concrete pavements that have reached the end of their service life are being crushed and used as the aggregate base material for reconstruction projects. Virgin aggregate is only used to make up the difference between the amounts of aggregate needed to construct the project and the amount of aggregate produced by crushing the old concrete pavement.

A great deal of testing has been performed to determine the effects of the recycled materials in the pavements, in particular HMA pavements. RAP has been approved for use as aggregate in HMA pavements, aggregate base material and embankment material. This has come about in part, due to the need to get rid of the excess material in the Chicago Land area where space is becoming a commodity and the recognition of the value of the asphalt cement and aggregate in the RAP.

The funding for the construction and maintenance of these roadways previously discussed vary greatly. Funding for the Interstates is overseen by the federal government. The US and State routes are generally a split between federal and state funding, i.e. 80% Federal and 20% State. The less traveled County and Township roadway projects can be funded by a variety of federal and state funding sources as well as local taxes.

As one may see, the demands on the federal funding can be immense. The Federal Highway Administration, FHWA, and the American Association of State Highway and Transportation Officials, AASHTO, are organizations dedicated to the development of proper standards and research for new design and construction methods and materials.

Each state Department of Transportation has representation in AASHTO. It is at this level that a large portion of the decision as to what methods our roads will be designed and what standards these roads must meet. The FHWA, with offices in each state, makes sure the federal funds are being spent appropriately.

Routine decisions made by the local and state engineers are in the development of a multi-year program which allocates future money to specific projects. This program can and does often change but it gives the tax payers an idea of where their money is going and how it may or may not affect them. The multi-year plan is further refined into an annual plan that divulges what projects will be during that particular fiscal year.

The more money the state has, typically the more projects will be done. This does not necessarily correlate to better materials being used. State officials have the task of meeting the public's needs with typically small budgets. Inevitably the public's needs and desires are larger than the amount budgeted. Projects are moved around depending on the political party in power at the time. Small planned projects may be cut due to funding needs elsewhere in the program such as to conduct emergency repairs on critical roads and bridges.

Interstates are typically constructed in Illinois out of Portland Cement Concrete over a stabilized base and improved subgrade. In the past the Illinois Department of Transportation has used jointed pavement but on the whole most concrete pavements are continuously reinforced. These pavements of yesteryear were as thin as 7 inches thick. The pavements of today are as thick as 14 inches. As expected, this is due to the new pavement design formulas to match with increasing traffic. Because of this a 40 year pavement design methodology was created. According to a presentation by the Illinois Department of Transportation at the Illinois Bituminous Paving Conference on January 9, 2008, eight jobs have been designed utilizing this methodology for HMA pavements. There have been three projects with 40 year PCC pavement designs, I-90/94 through Chicago, IL-74 through Peoria and I-80 near Minooka, Illinois. In general, the pavement and base courses are thicker. The base course aggregates are drainable and underdrains are installed at the edge of pavement. If pavements last longer then there should be less construction projects in a given time frame. In a 100 year time frame with a standard 20 year pavement life project (PCC pavement), theoretically there will need to be 5 reconstruction projects. With a 40 year pavement life the

number of projects in that same time frame drops to 2. Realistically, the number of reconstruction projects is less with the 20 year pavement due to the multiple rehabilitations using HMA resurfacings used to extend the life of the pavement.

The thicknesses of the pavements are determined by the Illinois Modified AASHTO method or by the mechanistic pavement design method. The stabilized subbase in Illinois is either a bituminous aggregate mixture, BAM, or a cement aggregate mixture, CAM. The improved subgrades are typically chemically modified with lime, fly ash or cement or are simply a crushed aggregate. The minimum thickness for the improved subgrade is 12 inches for state and federal routes within the borders of Illinois. The county and township roadways can be less.

The original AASHO test road was located in near Ottawa, Illinois and is now part of Interstate 80. The purpose of this test road was to determine how thin the various elements can be and still perform to the ever increasing standards expected by the traveling public. By using better materials at efficient or appropriate thickness' more miles of pavement may be constructed. This decision is done best when reconstruction or new construction projects are undertaken. Due to the small budgets in recent years very little reconstruction and new construction projects were undertaken. A typical design period for an IDOT designed roadway is 20 years. The 40 year pavement design was accomplished by using better quality source materials and engineering details. The primary goals of an extended life pavement are to thwart the pavement stresses on the pavement caused by heavy traffic volumes and recurring freeze-thaw cycles. It will be uncertain for many years before we will know if this was a good investment.

Extended life pavements are not limited to Portland Cement Concrete, PCC. Rather there is an effort to design an extended life Hot Mix Asphalt, HMA, pavement. The Federal Highways report FHWA-ICT-08-017 is a result of project IHR-R39 titled "Validation of Design Concepts of Extend Life Hot Mix Asphalt Pavements" (S. H. Carpenter, 2008). This project involved constructing and testing full-scale pavement sections at the ATREL site in Rantoul, Illinois. A goal of this project is to determine a total pavement thickness that would produce a tensile strain at the bottom of the pavement below 70 micro strains during the hottest period of the year (S. H. Carpenter, 2008). These pavement sections were constructed on both subgrade treatments typically used in Illinois, Lime Modified Soil and Aggregate Subbase. The asphalt industry has marketed the extended life HMA pavements as "Perpetual" pavement. Figure 1 is a picture of the ATLAS pavement loading system used in research project IHR-R39.

The perpetual pavement design concept involves a three layered system; a renewable surface, a middle rut-resistant layer and a lower fatigue resistant layer. The typical IDOT subgrade for full-depth hot-mix asphalt allows for 300mm (12 inches) of lime modified soil. IDOT proposed to replace the 300mm (12 inches) of lime modified soil with 300mm (12 inches) of aggregate subbase. This gradation of the aggregate subbase is a wide range of grain sizes but


Figure 1. ATLAS pavement loading machine

should result in a drainable layer (TRANSPORTATION RESEARCH CIRCULAR Number 503, December 2001). Underdrains are also part of this design.

The thickness of the pavement is determined by the existing IDOT design methods. Additionally, the use of polymers in the top 100mm to 150mm (4 to 6 inches) and the use of hydrated lime as an anti-stripping agent are required. The construction of the perpetual pavement is enhanced by the use of material transfer devices (MTD), the use of polymer primes between each lift, improved density specs and joint construction. There have been 8 extended life projects in Illinois. All were performing well as of January, 2008 (Illinois Bituminous Paving Conference, 2008).

The typical projects have been widening and resurfacing projects with Hot Mix Asphalt, HMA, with some interchange and urban reconstruction projects. The traveling public sees HMA projects as the government meeting their obligations with roadway projects in their area. However, when these resurfacing projects come too late in the life of the previous pavement, the travelers may have to deal with pot holes, large areas of rutting and other signs of pavement failure. It is imperative to maintain the pavements and rehabilitate in a timely manner.

In November of 2007, the HMA on Interstate 80 between mile post 73 and mile post 103, began to fall apart due primarily to the unusually high number of freeze-thaw cycles with a higher than normal precipitation. Initially the HMA surface and top binder lift began to ravel in the driving lane an area only the size of a basketball. The maintenance forces noticed this quickly and went to pick up bituminous patching material to fill this size of hole. By the time they returned the hole was one full lane width wide and 61m (200 ft) long. Other areas began

to show signs of this deterioration and quickly raveled away. The aggregate in the area of these problems had very little asphalt cement coating it. The asphalt cement in this harsh freeze thaw environment had stripped off the aggregate. The traffic quickly rolled a good portion of this material onto the shoulders.

On July 13, 2009, Illinois Governor Pat Quinn signed a $31 billion capital bill to decrease unemployment while taking care of the aging infrastructure and education. The bill includes $14.3 billion for roads and bridges, $7 billion for transportation projects such as high speed rail, $3.6 billion for primary education and $1.5 for higher education (Goldberger, 2009). This large program has posed a daunting task to decide when select projects are to be completed as well as what materials will be used.

The local availability of materials or the lack thereof greatly affects the cost of a project. Aggregates are used in all major pavement related pay items. The common material in everything from the shoulders, curb and gutter and all the pavement types used is aggregate. The life and quality of the pavement relies heavily on the quality of the aggregates.

The Illinois Department of Transportation, IDOT uses a Quality Management Program named Quality Control/Quality Assurance or QC/QA. One of the requirements of this program is that the aggregates used must be produced under the Aggregate Gradation Control System, AGCS. In this system the producer is responsible for the gradation control of their products. The quality assurance and quality is the responsibility of IDOT. A great deal of effort goes into these controls. The quality of an aggregate is labeled A, B, C and D with A being the best and D being the lowest quality allowed in the system.

There are aggregates that do not meet D quality. Each district has Limestone deposits but not all have Limestone quarries. Therefore not all districts have sources of quality aggregates. These aggregates have to be shipped in by truck, rail or barge to supply the needs of these areas. This cost of shipping increases the cost of the aggregate and therefore increases the cost of the pavement using that aggregate.

PCC pavement in Illinois requires “A” quality, freeze thaw resistant aggregate. HMA pavement can and often do use aggregates of quality lesser than that required for PCC pavements because of local availability. Locations without access to “A” quality aggregate have elevated first costs for PCC pavement.

Industry lobbying is an integral part of our system. It is not suggested that all industries hire a professional lobbyist but each company, group of companies as well as citizen groups have the ability to speak with government officials to express their concerns and wishes regarding a multitude of issues.

Companies in particular use this avenue to sell their wares such as engineering services, material industries such as concrete, aggregate, bituminous, geosynthetics, equipment, etc. Each product is to go through a rigorous investigation to determine if this material is right for Illinois highway projects.

This open door policy benefits the traveling public by constantly introducing new and innovative products that may reduce costs, increase the life of a roadway or make a process easier. Today’s engineer needs to keep an open mind but hold on to what has been learned from the past. This is not an easy task. Engineers are challenged to design it better, build it

faster and maintain it cheaper than in the past. In this vane the Materials Department of a Transportation Agency is proved to be an innovative piece to the ever increasing puzzle.

An argument in the geosynthetic industry about the use of geotextile fabrics verses the use of geogrids is waged from many points of view, the designer, the construction inspector and the supplier. The desire to have a separation layer between fine grained soils and aggregate bases has made a place in the market for the geotextile fabric. However, the stability provided by a geogrid has been proved in the laboratory and the field. Both product manufacturers claim their product will do both, separate and stabilize. Some engineers, to be safe are specifying the use of both products on the same project in the same location. Some manufacturers are now producing geogrids with a geotextile adhered to it. This is an example of the market pushing innovation.

The thought, design and testing involved in preserving of sustainable materials by using other materials such as recycled materials, waste materials and simply new materials used in the construction of highways is well worth the effort. The strides made in this industry may very well help another.

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