# COLLABORATION WITH INDUSTRY TO PROVIDE LEARNING OPPORTUNITIES FOR ENGINEERING STUDENTS

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## 1. INTRODUCTION

The Flexible Pavements of Ohio, Inc. (FPO) sponsors an annual hot-mix asphalt competition where student teams from a number of engineering schools in Ohio compete to design an asphalt mix to resist rutting. Rutting is defined as surface depressions in flexible pavements in the wheel path of vehicles as a result of excessive repetitions of heavy vehicles. The teams are provided with the same aggregates which are supplied to participating schools from one particular source.

The teams are then required to conduct some research to learn about rutting and what is being done to eliminate it from asphalt roadways. Students also learn about additives and modifiers used to enhance mix resistance to rutting. This year a group of two junior students at Ohio Northern University are participating in this competition. One of them is doing this as an Honor Contract Project and the other student volunteered for the sake of acquiring the hands-on experience. The students will produce a job mix formula for their design complete with literature review and life cycle cost analysis. Also, each team is required to present their findings to a panel of experts who will decide on the winning team based on a scoring system that evaluate actual laboratory results, technical report and oral presentation.

This competition allows students an opportunity to learn about asphalt mixes through practical hands on experience. Normally students that participate are eligible for scholarships that are annually awarded by FPO. This paper summarizes the objective, research and findings of the students who are supervised by their faculty member and assisted by a host laboratory in Findlay, Ohio. Assessment of students learning is also included.

Industry has often collaborated with engineering programs in a variety of ways. The industry is vital in curriculum enhancement and improvements. Many schools use real-world projects as a part of their senior design courses[2]. Other schools rely on the partnering with industry to provide learning opportunities to students. Some engineering courses utilize field trips to industrial facilities to give the students an insight of the real world of the engineering practice. Others may use resources provided by the industry to complement the learning experience of the students[3]. The project described in this paper is such an example of a partnership with industrial constituents to provide a practical hands-on experience to students.

### *1.1 Rutting of Asphalt Pavements*

Rutting has been a commonly occurring problem with roadways across the country. Rutting can be observed in asphalt pavements when the pavement surface in the wheel tracks is compressed or deformed after being subjected to repeated heavy loads from trucks and other heavy vehicles. Rutting can be the result of the compression of one or more layers within the pavement structure[1] .The pavement in the wheel path is depressed downwards and/or pushed outward. This makes it hard to control the steering of the automobile, and the ruts attract water when it rains.

### *1. 2 Objective of Competition*

The objective of this project is to design an asphalt mix that will resist rutting to a high extent. This objective will be accomplished by producing a number of mixes to determine the best percentages of the combinations of, asphalt cement, aggregates and an additive to reach an optimum percent of air voids in the final design mix. This project is part of a statewide competition, in which a number of student teams from different schools of engineering in Ohio compete to produce a rut-resistant hot-mix asphalt. Like any other competition, this one has its own parameters where the greatest challenge lies in determining the correct blend of aggregates to be used. The aggregates come in three size designations: # 8 Gravel, Natural Sand and Natural Crushed Screenings. Unlike crushed stone, gravel particles tends to be less frictional in an asphalt mix when subjected to heavy loads thus moving within the mix to cause rutting because of their smoothness and round geometric shape. On the other hand, crushed stones lock in with each other using their narrow angles and sharp edges, therefore, causing less movement and consequently less rutting.

### *1.4 Aggregate Selection*

Aggregate selection is one of the important steps in the process. The gradation requirements that were given for the target asphalt mix are consistent with the specifications of the Ohio Department of Transportation (ODOT) item number 441Asphalt Concrete for medium traffic. It was evident that the stone received from American Aggregates had very little rut resisting capabilities and did not match ODOT requirements in every grade of aggregate. In order to resist rutting the best types of aggregates to use are ones with fractured surfaces and stable structures. In the aggregates provided to design teams, the No. 8 Gravel was made of flat, elongated particles with smooth surfaces that created very little frictional capabilities. Also the No. 10 screenings were very fragile and susceptible to crushing under loaded conditions. Also, the Natural Sand supplied to design teams has smooth surfaces and low frictional capabilities. A blend of these aggregates was selected to meet the requirement set by ODOT for Item number 441 Asphalt Concrete.

## 2. SYNOPSIS OF STUDENT EXPERIENCE

### *2.1 Gathering Pertinent Information*

The student team representing Ohio Northern University in the competition was comprised of one female and one male junior. To prepare for the design the team first had to familiarize themselves with Superior Performing Asphalt Pavement technology (Superpave). Superpave optimizes an asphalt mix to resist permanent deformation and cracking due to fatigue and low temperatures. The traditional Marshall method of mix design considers primarily the asphalt binder, while Superpave takes all of the pieces of mix design into consideration, namely the selection of components, proportions of aggregate and binder by volume, and assessment of the mix after compaction. The Ohio Department of Transportation (ODOT), among many DOTS', has adopted Superpave technology. The team used Item 442 Superpave Asphalt Concrete of the 2005 Construction and Material Specifications published by ODOT as the primary guideline for their mix design.

The students also had to research asphalt additives and their effects on performance. Among their findings, the team found out that the Unique Pavement Materials Company manufactures a hot mix pavement modifier that is a high-performance adhesion promoter that is formulated to improve the performance and longevity of asphalt by improving adhesion and increasing the tensile strength ratio. Studies have shown it to increase a pavement's quality lifespan by over 30%. Also investigated were the benefits of polymer modified asphalt (PMA). PMA mixes significantly improve resistance to rutting, fatigue cracking and thermal cracking and extend the lifetime of a pavement. A publication from the Asphalt Pavement Alliance is available that quantifies the benefits of PMA. Dupont® manufactures a product called Elvaloy® RET, a reactive elastomeric terpolymer. It is mixed into asphalt cement in the form of solid pellets as the asphalt is being prepared for shipment to a hot mix plant. The pellets melt under high temperature and react with the asphalt to form a stable, homogenous binder material. DuPont reactive terpolymer has been used to modify asphalt since 1991. PMAs made with the new DuPont modifier now have been used in more than 26 states in the U.S., and in several other countries. While at the Ohio Transportation Engineering Conference in Columbus, Ohio (OTEC) the teams had the luxury of meeting several representatives from paving material companies. The two students inquired about their experiences with additives and collected information and brochures on several different pavement additives. It was finally decided to use Gilsonite HMA Modifier, produced by American Gilsonite Company who was generous enough to donate two cans of Gilsonite to our project. Gilsonite HMA Modifier is a naturally occurring hydrocarbon granular solid.

Gilsonite produces increased stability when mixed with asphalt cement or hot mix asphalt. Additionally, it reduces rutting, shoving, and other deformation resulting from loading, while increasing resistance to water stripping, fatigue, and thermal cracking. While Gilsonite affects a mix's properties differently depending on the amount added, typically 8-10% of the asphalt cement, by weight, is added. Since such small amounts are needed to increase the Asphalt Cement (AC) viscosity, Gilsonite is considered to be highly effective, efficient, and consequently, more cost effective. Moreover, because it can be added directly to the asphalt cement or aggregate, Gilsonite is easy to use. In studies to test resistance to rutting, the mixes with the highest concentrations of Gilsonite were found to be the best. The amount of Gilsonite used in final mix was based on the ODOT Supplemental Specification 857.02 which calls for a modified binder composed of 92% asphalt binder and 8% Gilsonite.

*2.2 Laboratory Mix Design*

Next, the team had to decide upon what performance grade asphalt cement binder to use. This decision made was based on the recommendation of several industry representatives and the binder used was graciously supplied by the Shelly Company, in Findlay, Ohio. Shelly Company also allowed the students to use their lab facilities and showed them all the sieving, mixing and testing procedures needed to conduct the project. The final material needed for the mix design, was the aggregate which was supplied to all participants by the sponsor of the competition, Flexible Pavements of Ohio from one of their member aggregate producers.

Having all the materials, time was then spent in the lab choosing an aggregate blend based upon the aggregates' gradation and ODOT target gradation limits. The material was then sieved to separate the aggregate into different sizes. Once separated by sieve size, mix samples were then made. The team had some material constraints so they began by choosing two AC binder contents 5.5% and 6.0%. Using sample sizes of 2000 grams and 4000 grams, the design gradation was applied to the remaining 94% and 94.5% of the weight that was to be composed of the aggregate blend. The batch weights of all sizes of aggregates were measured out and blended and put in the oven to heat. The AC Binder was also put in the oven to heat. In doing mix design it is important to keep all the materials, pans, bowls, mixers, utensils, etc. up to temperature.

Once everything was heated sufficiently, the Gilsonite, in powder form, was added to the aggregates and mixed in. The Gilsonite added was 8% by weight of the corresponding AC binder content. Next an indentation was made in the center of the aggregates to add the liquid binder. Asphalt contents of 5.5% and 6.0% of the total sample weight, minus the weight of the Gilsonite were added to the aggregates and mixed thoroughly with an electric Hobart mixer. A larger mixer was used for the 5000 gram samples and a smaller one for the 2000 gram samples. Once mixing was complete the sample were returned to the oven condition for approximately two hours. This allows the binder to soften again and be absorbed by the aggregate and evenly distribute throughout the mix.

The smaller 2000 gram samples were turn into loose particles to be used in the "Rice" density analysis of the designs. The samples were used to determine the maximum specific gravity and the density for each mix design. Once removed from the oven again the sample is cooled to room temperature and then broken down into small pieces, preferably no larger than the largest aggregate size. The mix is then weighed, to obtain the dry weight of the mix. Then the mixture is placed in a vacuum vessel and sufficient water at a temperature of 25° C is added to completely submerge the mix.

The vacuum is applied for fifteen minutes and then the vessel is completely filled with water and weighed. This gives the weight of the container, mix and water. A constant weight of the container filled only with water is then determined. The mix is then spread out to dry and then weighed again when completely dry giving the "SSD weight" of the mix.

The larger 5000 gram samples were used to make gyratory compacted pills. The mix is removed from the oven and then placed in to a mold which is then compacted by a gyratory compactor for 65 gyrations. The pill is removed, cooled to room temperature and the dry weight in air is taken.

It is then submerged in water for several minutes and its weight in water is recorded as it is submerged. The pill is then removed and damped dry and weighed again giving the Surface Saturated Dry (SSD) Weight.

This procedure was followed for all Asphalt Concrete (AC) binder contents tested. Our final mix design was determined to be original aggregate blend and 5.5% AC binder with 8% Gilsonite. The students were able to make six more gyratory samples of their final mix using the previous procedures. These samples were then tested at ODOT central facility in Columbus, Ohio. The samples were evaluated in a simulated experimental setup and the results were exceptional.

## 3. ASSESSMENT OF STUDENTS' EXPERIENCE

When the student team was told about the opportunity to complete a hands-on asphalt mix design project sponsored by Flexible Pavements of Ohio, they were intrigued, wary about their own inexperience in the area, but willing to try something new. Initially there were fears and doubt about their competence and knowledge in an area they knew very little about, but with some helpful guidance from the instructor, they were reassured that they were capable of completing the project successfully and that the main goal, to introduce students to hot mix asphalt design procedures and provide industry exposure would be met.

The instructor introduced the students to mix design and provided them with an overview of the required procedures. In addition, the students were introduced to the applicable specifications on hot mix asphalt in Ohio. Then, the students started learning more about the topic from suggested reading material and internet searches.

The project was frustrating at times because the team faced a lot of setbacks beyond their control, requiring much patience. However, in the limited time the students were able to press on to finish the project with time management and persistence. Additionally, teamwork was required not only in execution, but in motivating one another to complete the project. The students had no prior experience with asphalt, thus the terminology; materials, equipment, mix designs, aggregate blending, asphalt mixing, and testing were all new to them. Nevertheless, the industry partners were immensely helpful in providing information and insight, donating products and allowing the students the use of facilities.

The students had to endure through realistic constraints of shortages and delays in delivery of materials, coordination with industrial partners and project scheduling challenges. The students also had opportunities to put their professionalism and communication skills to work for them in a professional environment. Most importantly, they exercised their engineering judgment and common sense on a number of occasions. In certain instances, things could not be done according to methods and procedures nor according to industrial standards, but they managed to make the right call whenever needed.

In all, the students found this experience to be informative and exciting. In their own assessment of the experience as a whole, they noted that working under realistic constraints caused this experience to be exciting and challenging. The students also had a feeling of confidence in being able to use results from their own web research on pavements and asphalt modifiers in their final mix. They also cited the important role of communications in the industrial and professional environments. Their ability to write letters and e-mails to companies requesting materials and information about products and proper handling procedures of such products had proven to be a valuable asset to them.

## 4. CONCLUSIONS

The project proved to be an excellent learning experience enhancing the character and technical development of the students. This experience gives them an edge and provided an understanding that cannot be duplicated in their college classes. Hence, the students were appreciative of the opportunity to gain experience in an area entirely new to them. Such collaboration with industry had enabled undergraduate students to be involved in a research experience that would not have been entirely possible at an undergraduate institution. The benefits to the industry included the promotion of state of the art materials and technology. This competition allows also Ohio Northern University to be recognized by area industry for the preparedness and professionalism of its students and their ability to take on real-world challenges.

## 5. REFERENCES


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