SUSTAINABLE BASE COURSES

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ABSTRACT

At existing airports, re-aligning and replacing taxiways is a common practice due to reconfigurations of the operational area or just normal wear and tear. For example, with the arrival of the new “Super-Jumbo Jet” aircrafts, such as the Airbus A380, our nation’s taxiways will need widening and increased load capacity to accommodate the large aircrafts. It is common practice when removing and re-aligning taxiways to dispose of the material and replace it with new material, either asphalt or other base courses. We wanted to try and reuse some of this material to develop sustainable design, and reduce material costs.

Preliminary research in the Port Authority of NY & NJ Materials Laboratory investigated the possibilities of reusing existing asphalt pavement (RAP), lime-cement-flay ash base course (LCF) and blending it with Portland cement to create a sustainable base course. This research was successful and lead to the option of using either a new asphalt base or a blend of existing pavement and Portland cement in a contract to upgrade the taxiways at John F. Kennedy International Airport. The low bidder chose to use recycled pavement materials and blend it with cement on-site.

This sustainable option not only proved to be economical but efficient as well. The on-site blending of Portland cement with the removed pavement material saved in travel time and reduced truck traffic on the surrounding infrastructure. This paper will discuss in detail the following topics related to sustainable base courses:

- Preliminary laboratory results
- Sustainable base course mix design
- Batching and placement methods
- QC/QA procedures
- Test results

INTRODUCTION

With each passing year the world becomes smaller largely because many people are traveling more often. According to the International Air Transport Association, between 2005 and 2009 international passenger routes will grow 5.5% while international freight will grow 6.3%. To accommodate the increase in traffic, US airports are undergoing different tactics that will ultimately allow this growth while minimizing delays and problems with its costumers. The airports are trying to accommodate the future “super-jumbo” jet class of airplanes such as the Airbus A-380 and the Boeing Dreamliner. Other airports are re-configuring their operational geography to facilitate more flight slots in a given period. Either decision requires large reconfigurations or rehabilitations of the taxiways and runways. The widening and increased loading on these airfield pavements have led the Port Authority of NY & NJ to investigate the feasibility of cement-treated base courses as an alternative option to the conventional asphaltic base course. This led to the use of RAP, LCF and sand as an aggregate source for the cement-treated base, which was a very successful venture.

HISTORY AND PRELIMINARY LABORATORY RESULTS

The history of sustainable base course can be traced back to the use of roller-compacted concrete and lean concrete. Extensive research was performed in the materials laboratory of the Port Authority of NY & NJ into different mix designs that are characterized under roller-compacted concrete and lean concrete. These were the original mix designs (Table 1). As can be seen from this table, a low cement factor and a low water/cement ratio was targeted to achieve the predetermined targets.

Eventually it was proposed to substitute the coarse aggregate with Recycled Asphalt Product (RAP). Using Shilstone's combined gradation theory (Figure 1), the RAP was uniformly graded and was shown to produce similar results as the RCC and lean specimen. It was also a benefit to use the RAP since now the contractor could benefit from removal process of the contract. The milled asphalt product was now carted to a section of the airport where the contractor built an on-site plant to process the blend, add cement, sand, LCF and water and send it back to the jobsite for use as the base course.

Table 1.
Preliminary Research.

July 9, 2003		
	Roller Compacted	Lean Concrete
Cement, lbs.	170	250
Fly Ash, lbs.	170	250
Sand, lbs.	1475	1100
Stone, #467, lbs.	1900	2000
Water, lbs.	187	275
W/C	0.55	0.55
Air Content	N/A	N/A
Slump, in.	N/A	4
Compressive strength, psi:		
7 days	320	1250

Mix designs targeted both aggregate replacements with Lime, Cement, Flyash (LCF) and Recycled Asphaltic Product (RAP). It was unknown at the time, which replacement would perform better and which would provide the most economical solution. Ultimately, after various testing in the laboratory it was determined that a variation on Mix # 5 would be accepted. This variation entailed increasing the amount of RAP used and blending LCF with the other aggregates. It has been referred to colloquially as "econocrete".

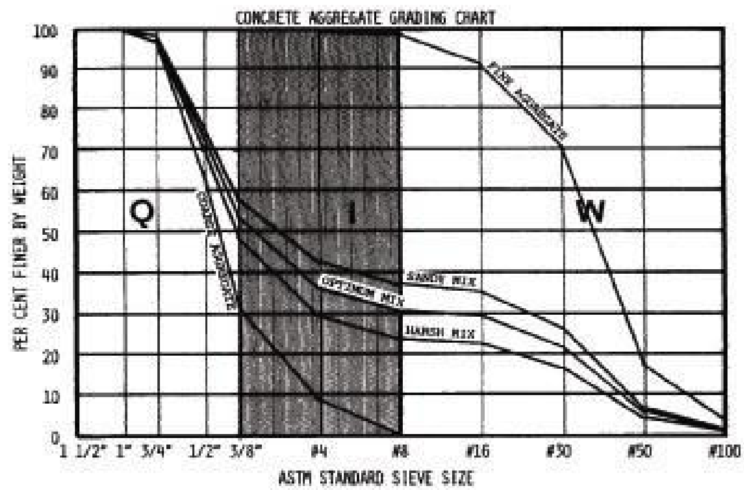

Figure 1. Gradation Chart (Shilstone [1])

Table 2.
Refined Mix Designs.
March 11, 2004

	Mix1	Mix 2	Mix 3	Mix 4	Mix 5
Cement, lbs.	500	500	500	500	500
"Brown" sand, lbs.	3100	1600	N/A	N/A	2300
"Grey" sand (LCF), lbs.	N/A	N/A	3100	1600	N/A
RAP (3/8"), lbs.	N/A	1600	N/A	1600	800
Water, lbs.	370	422	418	390	400
W/C	0.74	0.84	0.7	0.78	0.8
Air Content, %	3.8	4.8	4.4	6.1	4.2
Slump, in.	3.75	3.75	4.25	4.5	3.5
Compressive strength, psi:					
7 days	430	750	585	715	870
14 days	565	1000	740	855	990
28 days	775	1200	1080	1005	1390

BATCHING AND PLACEMENT METHODS

There exists both a dry and a wet process of placing the sustainable base course. The dry process consists of mixing in an on-site plant and then placing the material in dump trucks to the brought to the site. The plant is constructed and operated in the contractor's construction yard on the jobsite. It consists of a hopper, belt and auger system.

The reclaimed pavement material, both asphaltic product and LCF, is screened to the proper gradation sizes (Fig. 1) and placed in stockpiles in the contractor's yard. Before each day's production, the stockpiles are examined for proper gradation and moisture. The cement used for production is kept in a silo connected to the assembly line.

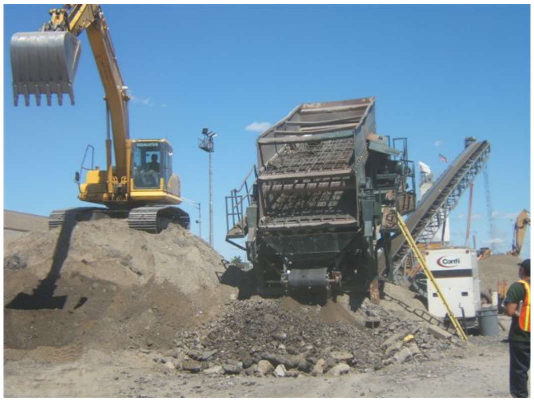

Figure 2. Screen and Gradation Process.

Figure 3. Cement Addition Process.

Figure 4. Final Product.

During production, loaders gather the appropriate material from the stockpiles and place them into specific hoppers at the beginning of the assembly line. The plant is completely automated and the exact weights of RAP and LCF drop onto the conveyor belt at the appropriate times. Then the designated amount of cement is dropped on top of the mix (Fig. 3) and the combination is carried to the next stage. A large auger mixer is calibrated so that when the pile of RAP, LCF and cement arrive it is mixed with the correct amount of water. The amount of mix water can be varied but it usually ranges between 9-12% of the total water. This also is controlled by computer and can be tweaked depending on the consistency of the final product and the environmental conditions. As a rule of thumb, the initial day's batch is done at the low end of the specified water content. It is then examined for consistency and corrected. This is done so that if there is a chance of rain or moist base conditions, the day's production is not lost.

At the bottom of the auger mixer, the final product is received on another conveyor belt that takes the product to large tandem dump trucks (Fig. 4). The tandem trucks are large 40-ton capacity trucks that are able to handle 22 cubic yards of material per trip. The product is then brought to the location for the day's construction ready to be placed. Each location is boxed out or formed by the surrounding land at grade level with a bed of sand ready to receive the econocrete from the plant. The truck then place the econocrete in no more than eight inch layers. The drawings call for four different depths: taxiway, heavy shoulder, light shoulder and erosion areas (Fig. 5a, 5b). For each layer, the material is first placed and then spread by a large spreader to the designated thickness. Pavement rollers compact the base course until it reaches optimum density, as tested by both the contractor's quality control manager and the Port Authority inspector. Once the material has achieved acceptable density results, it is spray sealed with a low-grade asphalt membrane. The base course is now ready to receive aeronautical pavement.

QUALITY CONTROL AND QUALITY ASSURANCE PROCEDURES

The Quality Control and Quality Assurance procedures are more extensive and complex with the sustainable base course. As part of the contractor's quality control plan, aggregate gradation control chart should be kept as a preventative measure, so as to spot whether gradation is the source of any field problem. It is recommended that the chart contain the running average of the last five gradations tests performed. There are action limits for falling out of gradation and moisture content specification and a suspension limit if the moisture content is below optimum or if the base is uncompactable. Corrective action must also be taken whenever two in-place density measurements are below 98% of the target or a single measurement is below 95% of the target. Strict specifications were also placed on the materials to be used for the sustainable base course. All reclaimed/recycled aggregate had to be pavement that was located within the project limits and must meet the gradation requirements listed below (Table 3a, 3b).

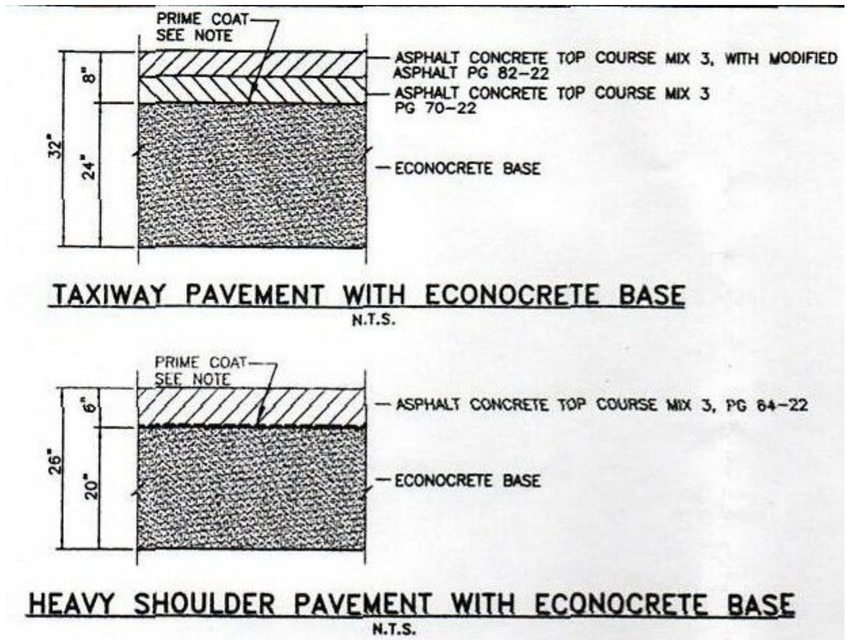

Figure 5a. Design Details.

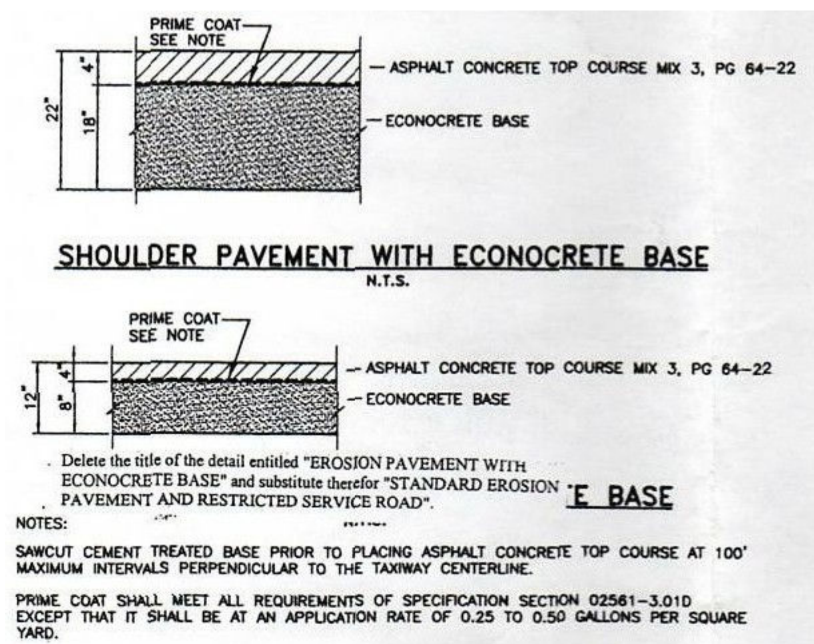

Figure 5b. Design Details.

Table 3a.
JFK 134.105 Gradation.

Sieve Sizes	RAP	Grey Sand/LCF	Brown Sand
2-1/2"	100	100	100
2"	100	100	100
1-1/2"	100	100	100
1"	97	98	98
3/4'	95	96	97
1/2"	85	91	93
3/8"	80	87	91
#4	60	77	83
#8	42	71	79
#16	29	64	74
#30	17	52	63
#50	9	28	28
#100	4	9	7

Table 3b.
JFK 134.105 Combined Gradation.

Combined Gradation	
1-1/2"	100
1"	90-100
1/2"	80-100
#8	50-85
#30	30-70
#100	0-10

The conventional procedure requires only one plant inspector making sure that the asphalt is batched correctly. Field placement of base courses is typically not inspected. Sustainable base course testing is a three-step process. First, the optimum density and moisture for that particular lot are determined. This is done at a mobile lab adjacent to the plant and a one-point proctor and moisture tests are performed for each lot of material that is produced. The materials inspector then watches the placement of the materials and notes on a drawing the area that was placed during that period. A day’s production is considered a lot of material and each lot is then divided into at least 3 sublots. A random system of placing cores is used and between 14 and 28 days 2 cores are cut from each sublot. Using this method, the cores are then returned to the lab where they are trimmed to eight inches, where possible, or anything greater than four inches where it is not possible. The cores are then capped according to ASTM C-617 and tested under ASTM C-39. The quality of this “econocrete” is a pay item on this contract and two categories must pass specifications: field density and compressive strength.

The following is a summary of the Port Authority of NY & NJ specification number 02242 and 02243 which details both the dry and wet process, respectively for a sustainable base course. An influence on this specification was the FAA specification P-306 which deals with cement treated base. The contractor must submit a mix design to be approved. This design must show results of 1,000 psi in 14 days and 1,500 psi in 28 days. Also, specimen weight loss at 12 cycles in a freeze-thaw test must not exceed 14%. The average percent density of the compacted base should be greater than 98% of the maximum laboratory density. The minimum average 28-day strength results should be 1,250 psi.

PRESENT EXAMPLE

A current contract that utilizes the sustainable base course is JFK 134.105 "The Relocation of Taxiway A and Rehabilitation of Taxiway B." The contractor submitted a mix design that was approved which can be seen below.

Table 4.
JFK 134.105 Approved Mix Design.

Cement, lbs.	Initially 600, lowered to 500
LCF, lbs.	1500
RAP, lbs.	1500
Gradation 50/50 blend	Percent passing
1.5"	100
1"	91.8
.5"	78.2
#8	51.9
#30	35.6
#100	6.4

Current contracts at John F. Kennedy International Airport have allowed the contractor to bid with either option. The winning bidder, (lowest, responsive responsible bidder) included the sustainable base course in his package. When asked about his bid items, it was made very clear that economy and efficiency were the main motivations for choosing to include the sustainable rather than the asphaltic base course. The construction method was more streamlined under this system as opposed to the conventional way of working. The contractor was given a sufficiently large plot of land on the airport to construct an on-site plant. During the removal phase of the project, the Recycled Asphaltic Product was carted to the site of the plant. It was then processed, graded and used to create the sustainable base course. This was then transported back to the jobsite during the placement phases of the contract. Many steps that were needed in the conventional way of doing business were now deemed excessive and unnecessary. Time is saved on the entire process because transport time is significantly reduced. Also waiting on aggregate shipments is taken out of the equation because the material is replaced with what has been removed previously.

TEST RESULTS

The initial laboratory test results were bordering on the strong side, between 2,000 and 3,000 psi. After a few revisions, the cement content was lowered to produce laboratory design strength of 1,250 psi. Once the contractor began to mix and place the base course, the compressive strength tests on the field specimens were consistently 400 psi above the required 1,250 psi at 28 days. In a value engineering effort, the contractor recommended reducing the cement content from 600 to 500. After it was shown to provide passing test results, this change was approved.

The test results have been satisfactory with failures occurring few and far between. The average 28-day compressive strength results (based on ASTM C-39) are 1650 psi, with a standard deviation of 260 psi and a coefficient of variation of 0.16. The quality of the material has been proven through the field tests and the contractor has continually supplied the job with a consistent product.

GREEN CONSTRUCTION

The idea of the sustainable base course also provides a green product that benefits both the owner and the community. Currently the environmental movement is a very popular and strong force throughout industry in America. One of the most notorious polluters of the environment is the construction industry and therefore anything that can be done to minimize this negative effect is seen as a great positive. The concept of a sustainable base course is one that is simplistic it could be easily substituted for conventional base courses.

Four aspects of the econocrete base course process help categorize itself as a green construction process. These aspects are:

- Management of Natural Resources.
- Reducing Energy Consumption.
- Reducing Emissions.
- Lowering Community Impact.

A large percentage of construction materials delivered to a jobsite are wasted or inefficiently used. This results from poor designing and planning but also specifications that are too lenient when it comes to materials selection. One way to remedy this is to initiate the idea of re-using and recycling materials during the planning stages of the job. This will facilitate the acceptance of a sustainable construction job and aid in specifying certain items that the contractor may otherwise not perform. Reducing the requirement for new materials also does away with the obvious transportation emissions needed for delivering this material to the jobsite.

The construction industry has the dubious recognition of being the most pollutant industry in the world. Much of this is attributed to emissions arising from the various machine and vehicles used throughout the construction process. Aside from pollution of vehicles, noise and dust cause by deliveries and on-site activities cause nuisance to the local community. Part of the responsibility of the owner is to oversee the contractor to make sure that these are minimized.

The consumption of fossil fuels leads to the production of greenhouse gases, mainly Carbon Dioxide. These emissions contribute to climate change, which is predicted to cause an increased number of storms, more droughts and higher sea levels. Fossil fuels are our main source of energy. They are a finite resource, which means that they will eventually run out. The construction industry consumes energy through:

1. The extraction, processing, manufacturing and transport of construction materials and products

2. The transport of product manufacturing wastes.

3. Construction and demolition activities.

4. The transport of construction and demolition wastes.

5. Operations on construction sites such as contractors' offices.

Vehicles that travel on the network also consume energy. The transport of materials for construction and maintenance is a major energy issue. Through the contract specifications, the Authority is mandating the use of local materials and recycled products. This has greatly reduced the number and length of vehicle journeys required in construction and maintenance activities.

The Authority takes great pride in its dealing with the local community. The respect for people, especially those directly affected by a construction project, is one of the top priority during construction. One way this is done is incorporating the opinions of those affected and managing and making decisions taking into account the impact it will have on the community. The local community does not only include those within a certain proximity of the construction site but also those that live and work along the major transportation routes to and from the jobsite. Minimizing the traffic and transportation repercussions is also considered a major concern of the Authority.

The use of the sustainable base course addresses in a positive way each of the above issues. It manages efficiently and effectively natural resources because more than eighty percent by weight is recycled material. Only the cement used is new production that has to be transported to the site. Using econocrete also lower the total emissions for the production of the subbase. Instead of producing each individual constitute new and transporting it to the site to be placed, the recycled material is taken from the jobsite and batched at an on-site plant and then brought back to the job. A truck now travels in one day what it would have in a single delivery trip. The energy consumption is also less because again econocrete is made from recycled material and batched on-site. Also most other subbase products are asphalt based which is in and of itself a process that requires large amounts of energy. Finally, econocrete is great when the community impact is considered. Since almost everything happens on the jobsite, the surrounding community is not only impacted less but most of the time the local inhabitants do not even know that construction is occurring. This is a product that succeeds on every environmental level.

SUMMARY

Econocrete is a cheap and effective alternative for aeronautical subbases. The extensive lab testing and subsequent usage in the field has given us more than enough faith in the performance and economy of the product. The fact that low bid contractor informed us that it was in fact the econocrete that allowed him to be the low bidder further reinforced our findings. What should not be lost however, is the fact that econocrete is a product that is also beneficial to the environment. The savings on energy consumption and vehicle emissions because of the nature of the recycled constituents allow it to be sustainable and profitable. It is not a stretch of the imagination that more airports throughout the United States will move towards a sustainable base course in the near future.

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