capable of measuring uncured concrete, cured concrete, or asphalt.

The sensors can operate in a construction environment with little or no maintenance under the environmental conditions previously specified. The sensors measure the average height of a footprint about 2 in. in diameter. The sensors are not adversely affected by tining because they measure the peaks of the tined surface and disregard the valleys.

ACKNOWLEDGMENTS

A New Process and Apparatus for Making Asphalt Concrete

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ABSTRACT

The new Energy Efficient Mixer (EEM) makes possible a pollution-free and energy-efficient process. The EEM can heat and mix materials to a final temperature ranging from 60°C to more than 204°C (140°F to 400°F). There are three main components associated with the complete plant: a gas- or oil-fired thermal liquid heater (heater), a sealed and indirectly heated mixing chamber (processor), and the condensing coil-heat recovery bins (heat recovery). Compared with current processes for making asphalt concrete, the pollution-free EEM uses 20 to 30 percent less fuel per ton of product. This fuel economy is based on production of 140°C (280°F) mixture while removing 5 percent moisture. When the moisture content of the raw material exceeds 5 percent, the EEM process becomes even more efficient compared with existing processes. EEM thermal efficiency is made possible by effective recovery of the heat of vaporization contained in the removed moisture. In addition to cleanly and efficiently producing all types of asphalt concrete, EEM can produce new mixtures with a predetermined optimum moisture content. This optimized asphalt concrete mixture is produced by controlling the mixture temperature and the vapor pressure within the sealed mixing chamber. Furthermore, oxidation of the mixture is minimized because the heating and mixing take place within a sealed and pressurized chamber.

Current equipment for making asphalt concrete uses mostly direct-fired processes. In a batch process, the aggregates are directly heated and then mixed with the asphalt cement in a pugmill mixer. In a continuous process, generally known as a drum mix process, the mixture of aggregate and asphalt cement is directly heated. Current systems, particularly drum mix processes, give off and vent to the atmosphere significant amounts of hydrocarbons (blue smoke) and particulate matter. These systems also emit significant amounts of noise, and process problems are exacerbated by attempts to recycle asphalt concrete.

There have been attempts to control emissions from current processes by adding fabric filters and wet scrubbers. However, nonparticulate emissions are not effectively controlled by these devices. Problems such as mixture deficiencies due to collected microfine particulates (baghouse fines); corroded ducts, fans, and scrubbers (fuel); and baghouse fires or explosions (hydrocarbons) have resulted from these control efforts.

Current processes suffer from inefficient fuel use because they exhaust the removed water vapor to the atmosphere. This generally represents between 30 and 50 percent of the thermal energy consumed. With current systems, minimal recovery of the exhausted thermal energy would require large amounts of surface area. This is because of the presence of air (60 to 90 percent by volume) that is used as a medium to remove the water vapor.

For reference and to serve as a baseline of data, the following heat balance is for a typical 200-ton-per-hour (TPH) direct-fired asphalt concrete drum mix plant. The conditions are 140°C (280°F) mixture while removing 5 percent moisture.

Q_{AGG} = TOTAL MIX x %AGG x SP HEAT x TEMP RISE

Q_{AGG} = 400,000 #/HR x .94 x .25 BTU/# x (280°F-70°F)

Q_{AGG} = 18.7 x 10^6 BTU/HR

Q_{ASP} = 0 (6% by weight delivered at 280°F)

Q_{HOH} = TOTAL MIX x %AGG x %HOH x HEAT REQD

Q_{HOH} = 400,000 #/HR x .94 x .05 x 1112 BTU/#

Q_{HOH} = 20.9 x 10^6 BTU/HR

Q_{USED} = Q_{AGG} + Q_{HOH}

Q_{USED} = 40.6 x 10^6 BTU/HR

Next add losses for excess air, combustion products, and shell for a total of 20 percent.

Q_{REQ} = 40.6 x 10^6 BTU/HR/.80

Q_{REQ} = 50.8 x 10^6 BTU/HR

Using fuel with a heating value of 142,000 Btu per gallon would yield the following fuel consumption:

GALLONS = 50.8 x 10^6 BTU/HR/142,000 BTU/GAL

GALLONS = 358 GAL/HR

GAL/TON = 358 GAL/HR/200 TPH

GAL/TON = 1.8

Therefore, the theoretical fuel consumption under the previously stated conditions for a current drum mix type process would be about 1.8 gal per ton.

DESCRIPTION OF EEM

Figure 1 shows a complete, full-scale plant with the main components: the thermal liquid heater and the associated pump and piping system, the sealed and indirectly heated mixing chamber (processor), and the condensing coil-heat recovery bins.

The new process uses an indirectly heated shaft and blade assembly within a sealed mixing chamber. The hollow shaft screw conveyor-mixer assembly is supported on each end by a bearing and is driven by variable speed motor reducer assemblies. When the process is operating, the shaft is rotated at 5 to 10 rotations per minute. Slow rotational speed minimizes blade and shaft wear. The screw conveyor-mixer heats and mixes the mixture while propelling it to the discharge end. The outlet device and the main shaft speed are used to control the mixture level within the mixing chamber.

The EEM processor is heated by heat transfer fluids such as Dowtherm G, Mobiltherm 603, and Therminol 66. The fluids are efficient and will remain stable and efficient for years. A three-way bypass valve located just beyond the heater outlet controls the volume of heated fluid delivered to the processor unit. Using the fluid bypass control method, the mixture discharge temperature can be held within a range of 3°C (5°F). Rotary joints connect the stationary pipes to the rotating shaft assembly. The fluid passes through the inlet rotary joint, each blade, the jacket, and finally the outlet rotary joint. The system is so efficient that, with the fluid outlet temperature at 315°C (600°F), the temperature of the aluminum skin covering the insulated processor is about 60°C (140°F). Thermal liquid heaters have been built as large as 50 million Btu per hour output, generally operate at better than 80 percent efficiency, and produce little noise when running. They operate on gas or oil and are automated for easy operation.

To obtain fuel economy, the EEM process includes condensing coil-heat recovery units contained within the jacketed cold feed bins. The condensing coils condense any unwanted saturated steam and also preheat the cold feed materials. When the EEM process reaches a steady-state condition, the cold feed materials exiting from the bins are preconditioned to 60°C (140°F) and have 10 to 30 percent less moisture. Using this technique, EEM can efficiently condense the saturated steam (exhausted by virtue of its own pressure) generated by the sealed mixing process and thereby recover the previously wasted energy.

EEM PROTOTYPES

Two fully operational prototypes have been assembled
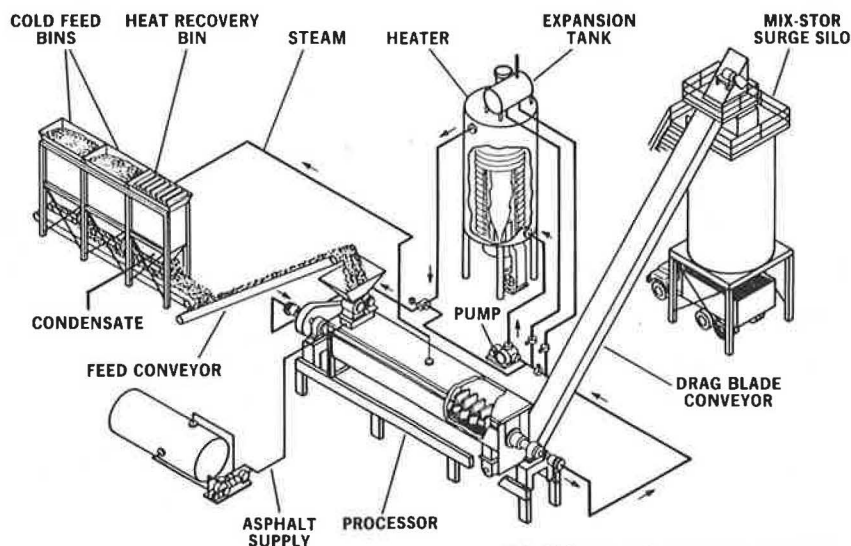
FIGURE 1 Diagram of a complete, full-scale EEM plant.

and used. The first prototype, a batch or unsteady-state process, was assembled in 1978. It could produce from 300 to 800 kg per hour (1/3 to 1 ton per hour) and was heated with steam at 185°C (365°F).

The second prototype, a continuous or steady-state process, was built during 1980 and 1981. It can produce from 10 to 13 metric tons per hour (12 to 15 tons per hour) of 121°C to 138°C (250°F to 280°F) mixture while removing 5 percent moisture. The steady-state prototype has produced hundreds of tons of virgin and recycled mixtures over a wide temperature range (60°C to 204°C).

During test runs of both prototypes, numerous samples were taken and tests were performed on the raw materials, the mixtures, and the condensate. The condensed water was tested and compared to standard drinking water specifications. The following table gives the test results. These results are in compliance with 10 of 11 limits for drinking water.

Tested	Result (mg/L)	Specification (mg/L)
Total dissolved solids	28	500
Phenolphthalein alkalinity	0	15
Total alkalinity as $CaCO_3$	10	15
Carbonate alkalinity	0	120
Chloride as Cl	1.7	250
Sulfate as SO_4	3.5	250
Total hardness as $CaCO_3$	10	35
Magnesium as Mg	0.5	125
Iron as Fe	1.1	0.3
Manganese as Mn	0.05	0.3
Turbidity	10	10

The following is a heat balance for the new EEM without heat recovery while producing the same 200 TPH of asphalt concrete. The conditions are 140°C (280°F) mixture while removing 5 percent moisture.

Q_{AGG} = TOTAL MIX x %AGG x SP HEAT x TEMP RISE

Q_{AGG} = 400,000 #/HR x .94 x .25 BTU/#
            x (280°F-70°F)

Q_{AGG} = 18.7 x 10^6 BTU/HR

Q_{ASP} = 0 (6% by weight delivered at 280°F)

Q_{HOH} = TOTAL MIX x %AGG x %HOH x HEAT REQD

Q_{HOH} = 400,000 #/HR x .94 x .05 x 1112 BTU/#

Q_{HOH} = 20.9 x 10^6 BTU/HR

Q_{USED} = Q_{AGG} + Q_{HOH}

Q_{USED} = 40.6 x 10^6 BTU/HR

Next add losses for the thermal liquid heater and pumping system (80 percent overall efficiency):

Q_{REQ} = 40.6 x 10^6 BTU/HR/.80

Q_{REQ} = 50.8 x 10^6 BTU/HR

Using fuel with a heating value of 142,000 Btu per gallon would yield the following fuel consumption:

GALLONS = 50.8 x 10^6 BTU/HR/142,000 BTU/GAL

GALLONS = 358 GAL/HR

GAL/TON = 358 GAL/HR/200 TPH

GAL/TON = 1.8

Therefore, the theoretical fuel consumption for the new EEM process with no heat recovery (venting steam to atmosphere) is the same as that of a current drum mix process. Empirical data from record runs of the EEM steady-state prototype without heat recovery produced the same results.

The following calculation is for the new EEM process and apparatus making the same 200 TPH of asphalt concrete. The conditions are the same 140°C (280°F) mixture with 5 percent moisture removal. This analysis includes the addition of the condensing coil-heat recovery bins. Two assumptions that have been verified by empirical data from the prototypes are: When exiting from the heat recovery bins, the feed aggregate is preconditioned to 60°C-70°C (140°F-160°F) and has 10 to 30 percent less moisture. A moisture removal level of 30 percent and complete recovery of the heat of vaporization (no subcooling) have been used for this calculation.

Q_{AGG} = TOTAL MIX x %AGG x SP HEAT x TEMP RISE

Q_{AGG} = 400,000 #/HR x .94 x .25 BTU/# x (280°F-140°F)

Q_{AGG} = 13.2 x 10^6 BTU/HR

Q_{ASP} = 0 (6% by weight delivered at 280°F)

Q_{HOH} = TOTAL MIX x %AGG x %HOH x HEAT REQD

Q_{HOH} = 400,000 #/HR x .94 x .035 x 1042 BTU/#

Q_{HOH} = 13.7 x 10^6 BTU/HR

Q_{USED} = Q_{AGG} + Q_{HOH}

Q_{USED} = 26.9 x 10^6 BTU/HR

Next add losses in the thermal liquid heater and pumping system (80 percent overall efficiency):

Q_{REQ} = 26.9 x 10^6 BTU/HR/.80

Q_{REQ} = 33.6 x 10^6 BTU/HR

Using fuel with a heating value of 142,000 Btu per gallon would yield the following fuel consumption:

GALLONS = 33.6 x 10^6 BTU/HR/142,000 BTU/GAL

GALLONS = 237 GAL/HR

GAL/TON = 237 GAL/HR/200 TPH

GAL/TON = 1.2

Thus, while using 1.2 gal per ton the new EEM process uses 30 percent less fuel compared to the 1.8 gal per ton used by current process.

The heat value (Q_{HOH} contained in the steam off) is the steam being removed by its own pressure from the EEM processor. Because condensate subcooling is not considered at this time, the heat value available at the bins is

$Q_{AVAILABLE}$ = 400,000 #/HR x .94 x .035 x 970 BTU/#

$Q_{AVAILABLE}$ = 12.8 x 10^6 BTU/HR

To check for a balance, aggregate in the condensing coil-heat recovery bins from ambient 21°C to 60°C (70°F to 140°F) would require

$Q_{\text{AGG IN BIN}} = 400,000 \ \#/\text{HR} \times .94 \times .25 \times (140°\text{F}-70°\text{F})$

$Q_{\text{AGG IN BIN}} = 6.6 \times 10^6 \ \text{BTU/HR}$

$Q_{\text{HOH OFF BIN}} = 400,000 \ \#/\text{HR} \times .94 \times 0.15 \times 1112 \ \text{BTU/}\#$

$Q_{\text{HOH OFF BIN}} = 6.3 \times 10^6 \ \text{BTU/HR}$

$Q_{\text{TOTAL USED}} = 12.9 \times 10^6 \ \text{BTU/HR}$

From this, the heat value coming from the EEM processor to the condensing coil-heat recovery bins is shown to be 13,700,000 Btu per hour. The available amount for recovery is 12,800,000 Btu per hour. The total taken was 12,900,000 Btu per hour.

Variations in moisture content, materials testing, process control, and recordation of events have provided a range of results. Early prototype hardware has provided a range of efficiency (compared to the current art) of 10 to 23 percent less fuel during record runs. Improvements in future generations of the EEM process will make a 30 percent fuel saving possible.

NEW PRODUCT DISCOVERIES

In addition to the EEM fuel economy of 20 to 30 percent when making typical 140°C to 150°C (280°F to 300°F) mixtures, additional fuel savings of 10 to 20 percent are possible. By using an indirectly heated and sealed processor, product temperature and vapor pressure are the new variables and asphalt concrete with a controlled moisture can now be produced. Using the steam vapor pressure to develop and control an optimum moisture content makes it possible to gain a reasonable heat value by reducing mix temperatures from 140°C to 104°C (260°F to 220°F).

Standard tests on asphalt concrete made in accordance with current practices provided base information about specific gravity and stability for a particular set of ingredients. Using the same standard tests on mixtures produced by EEM provided the following: At the optimum discharge temperature and pressure, in this case 104°C (220°F), the specific gravity and stability of the product made with EEM are significantly greater than the specific gravity and stability of current practice material compacted at the same temperature. The data substantiate a specific product optimum moisture content. Optimum discharge moisture content is defined as the amount of moisture that will impart the maximum specific gravity and stability at the lowest possible temperature. By using EEM with heat recovery and the new mixtures made possible with EEM, fuel reductions of 40 to 50 percent are attainable.

The following is a heat balance for the new EEM process and apparatus making the same 200 TPH of asphalt concrete. This example case has conditions of 104°C (220°F) mixture with 5 percent composite moisture. The process will remove 4 percent and leave 1 percent at 1112 Btu/# in the product at discharge.

$Q_{\text{AGG}} = \text{TOTAL MIX} \times \%\text{AGG} \times \text{SP HEAT} \times \text{TEMP RISE}$

$Q_{\text{AGG}} = 400,000 \ \#/\text{HR} \times .94 \times .25 \ \text{BTU/}\# \times (220°\text{F}-120°\text{F})$

$Q_{\text{AGG}} = 9.4 \times 10^6 \ \text{BTU/HR}$

$Q_{\text{ASP}} = 0$ (6% by weight delivered at 280°F)

$Q_{\text{HOH}} = \text{TOTAL MIX} \times \%\text{AGG} \times \%\text{HOH} \times \text{HEAT REQD}$

$Q_{\text{HOH}} = 400,000 \ \#/\text{HR} \times .94 \times (.028 + .01) \times 1042 \ \text{BTU/}\#$

$Q_{\text{HOH}} = 14.9 \times 10^6 \ \text{BTU/HR}$

$Q_{\text{USED}} = Q_{\text{AGG}} + Q_{\text{HOH}}$

$Q_{\text{USED}} = 24.3 \times 10^6 \ \text{BTU/HR}$

Next add losses in the thermal liquid heater and pumping system (80 percent overall efficiency):

$Q_{\text{REQ}} = 24.3 \times 10^6 \ \text{BTU/HR}/.80$

$Q_{\text{REQ}} = 30.4 \times 10^6 \ \text{BTU/HR}$

Using fuel with a heating value of 142,000 Btu per gallon would yield the following fuel consumption:

$\text{GALLONS} = 30.4 \times 10^6 \ \text{BTU/HR}/142,000 \ \text{BTU/GAL}$

$\text{GALLONS} = 214 \ \text{GAL/HR}$

$\text{GAL/TON} = 214 \ \text{GAL/HR}/200 \ \text{TPH}$

$\text{GAL/TON} = 1.1$

When using 1.1 gal per ton, the new EEM process and apparatus use about 40 percent less fuel than the 1.8 gal per ton consumed by current process equipment.

Because condensate subcooling is not considered at this time, the heat value available to the bins or cold feed is

$Q_{\text{AVAILABLE}} = 400,000 \ \#/\text{HR} \times .94 \times .028 \times 970 \ \text{BTU/}\#$

$Q_{\text{AVAILABLE}} = 10.2 \times 10^6 \ \text{BTU/HR}$

To check for balance, aggregate in the condensing coil-heat recovery bins from ambient 21°C to 50°C (70°F to 120°F) would require

$Q_{\text{AGG IN BIN}} = 400,000 \ \#/\text{HR} \times .94 \times .25 \times (120°\text{F}-70°\text{F})$

$Q_{\text{AGG IN BIN}} = 4.7 \times 10^6 \ \text{BTU/HR}$

$Q_{\text{HOH OFF BIN}} = 400,000 \ \#/\text{HR} \times .94 \times .012 \times 1112 \ \text{BTU/}\#$

$Q_{\text{HOH OFF BIN}} = 5.0 \times 10^6 \ \text{BTU/HR}$

$Q_{\text{TOTAL USED}} = 9.7 \times 10^6 \ \text{BTU/HR}$

The available amount for recovery is 10,200,000 Btu per hour. The total taken is 9,700,000 Btu per hour.

BENEFITS

Some of the benefits of the EEM process are

- No noise pollution;
- Lower mix temperature;
- 100 percent recycled mixtures;
- No pollution control equipment;
- Lower fuel consumption;
- All virgin-type mixtures;
- No pollution control costs;
- Emission reduction credits;
- Better temperature control;

- Reduced oxidation of mixtures;
- Less CO_2 as a result of less fuel;
- Emulsion, cutback, or sulfur mixtures;
- No particulate or hydrocarbon emissions;
- Clean water by-product/water conservation; and
- Investment credits not otherwise available.

Letters patent obtained regarding this invention are USA No. 4,245,915 and No. 4,378,162, Australia

No. 519,913, Great Britain No. 8,027,237, and Canada No. 1,148,935. Other foreign patents pending.

Unified System for Contract Management in Pennsylvania

JAMES W. SLAUGHTER

ABSTRACT

Before the 1980s the Pennsylvania Department of Transportation managed the various functions that surround construction contracts by using an unwieldy combination of manual and automated procedures. One of the department's major data processing development projects during 1981-1982 resulted in the implementation of a new contract management system. That system, which is now used to administer construction contracts, enables contracts personnel to capture initial design estimates, maintain a standard items catalog, develop bid proposal packages, maintain a library of standard special provisions, tabulate and evaluate bids, certify and monitor all contractors, prepare the contract itself, track contract-contractor relationships, monitor automated pricing data on standard items, adjust active contracts via work orders, estimate and process payments to contractors, forecast cash flow requirements, monitor any litigation, and close out completed projects. The background, basic characteristics, and costs and savings of Pennsylvania's contract management system are described.

Since 1979 several steps have been taken in Pennsylvania to better manage construction activities and to fully integrate all functions associated with highway program management. Various automated systems, which take advantage of on-line computer terminals and shared data bases, now support and promote improved program planning and management. More information on the systems and the ways in which department personnel use those systems has been published in other papers (1,2).

The purpose of this paper is to describe the contract management system used by the Pennsylvania Department of Transportation to administer construction contracts.

SYSTEMS ENVIRONMENT

The management information systems for the Pennsylvania Department of Transportation are housed in the central office in Harrisburg. The computer mainframe has 32 megabytes of main memory and 70,773 megabytes of additional disk storage. The information for all the systems mentioned in this paper is stored in direct access disk devices and is manipulated by modern data base management software. The application systems themselves were designed, tested, and implemented totally within the framework of the department's formal data processing development methodology.

There are more than 1,400 cathode ray tube (CRT) terminals and printers in the department's data communications network. All 11 of the engineering district offices and nearly all central office organizations access and update data via these terminals and printers. Figure 1 shows a representation of the department's data communications network.

BACKGROUND

Construction contract activities are better understood when viewed from the perspective of the department's business groups. Of three major business groups comprising the Pennsylvania Transportation Department--Commonwealth Transportation Systems Group, Driver and Vehicle Services Group, and Municipal Grants Management Group--the "roadway business" in the Commonwealth Transportation Systems Group is predominant. Because the department owns and operates its roadway business and, thus, controls all key performance areas, integrated highway program management has been recognized as a key success factor in the department's turnaround during the last 4 years. As a result, the department has evolved toward a data processing strategy in which "integration" has become a means to an end (i.e., increased productivity and improved services).

The concept of integration is increasingly demonstrated throughout the department. For example, the highway programming process in Pennsylvania has developed into an explicit and visible process by which management allocates resources and integrates these decisions into its production process.