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AN INTRODUCTION TO OPTIMIZING THE USE OF MATERIALS AND ENERGY IN TRANSPORTATION CONSTRUCTION

The construction of transportation facilities consumes vast quantities of materials. The annual figures are in billions of tons of aggregate and millions of tons of asphalt and portland cement and do not include the billions of tons of earth that is excavated, moved, shaped, compacted, and stabilized each year. These large quantities of materials cost money and energy to produce and place in a transportation facility.

In view of today's inflation, reduced material supplies, and curtailments of energy, an examination of the consumption of materials and energy and attempts to further optimize their use are needed. Therefore, the Federal Highway Administration, the Energy Research and Development Administration, and the Federal Energy Administration sponsored a 3-day workshop on Optimizing the Use of Materials and Energy in Transportation Construction, November 12-14, 1975, which was conducted by the Transportation Research Board. Fifty-four people from state transportation departments, federal governmental agencies, equipment manufacturers, material suppliers, trade associations, and universities attended. This Special Report contains the workshop proceedings.

The workshop participants heard from 4 keynote speakers, whose papers are given in this report. In the first paper, McKetta states that the energy crisis is real and serious. Furthermore, the energy situation will continue to get worse. Data given in Table 1, which are not in his paper but were received from him in a private communication, show the energy consumption in the United States in 1975. Transportation of people and goods consumes 25 percent of the total energy while all raw material processes consume only 6 percent. A natural question is, Why consider energy consumption in transportation construction when the greatest user is the transportation vehicle—the automobile? It is true that the automobile is the largest consumer of energy, but we cannot close our eyes to any energy consumer. Everything must be examined, scrutinized, questioned, evaluated, and ultimately optimized if we are to significantly reduce energy use. Transportation construction does consume significant quantities of energy, and energy must be conserved! It is necessary and timely that we examine our practices with the view to optimization.

Optimization is the key word! Optimizing means conserving scarce and expensive items by perhaps increasing the use of more plentiful items. Optimization means consuming 5 additional units of energy in a particular type of transportation construction to conserve 10 units of energy in automobile use, a net savings of 5 units of energy. The second keynote paper, by Chiogioji, indicates how energy implications can affect roadway decision making. The third keynote paper, by Marek and Jones, discusses the construction materials situation and points out where materials may be in short supply, and the fourth, by Cianchette, presents one contractor's view of how energy and materials can be optimized.

The subject of optimizing the use of materials and energy in transportation construc-

Table 1. Percentage of energy use in the United States in 1975.

Use	Industry	Commercial	Residential	Total
Transportation	9.1	1.0	15.0	25.1
Steam	16.7	–	–	16.7
Heating	11.5	6.9	11.0	29.4
Electrical drives	6.0	0.5	1.4	7.9
Raw materials (chemical)	5.5	–	–	5.5
Water heating	0.9	1.1	2.0	4.0
Air conditioning and refrigeration	0.1	2.9	2.3	5.3
Lighting	0.1	0.2	1.2	1.5
Electrolytic processing	1.2	–	–	1.2
Cooking	–	0.2	1.1	1.3
Other	0.1	0.2	1.8	2.1
Total	51.2	13.0	35.8	100.0

tion was examined by workshop participants in 7 sessions, each assigned a topic. In the sessions on each topic, participants were asked to identify current practices that conserve energy and materials in construction, suggest innovative practices that might be tried in construction and materials technology, and delineate research needs in these areas.

Participants recognized that, although "best" efforts toward optimization are always made, true optimization is seldom reached. Furthermore, as emphasized in the keynote papers, the bases for judgments are continually changing, and this new factor—energy—is having and will have an increasingly significant (if not overriding) influence on all future decisions concerning transportation construction. Optimization can only be achieved by full consideration of all factors—including energy—in their proper perspective.

Each topic chairman prepared a report summarizing the results of the discussions, and these 7 reports follow the 4 keynote papers in this Special Report. The following paragraphs introduce each of the 7 topics.

1: BINDING AGENTS

Binding agents in current use, or being considered for use, include asphalt products, hydraulic cement, lime, lime-fly ash, fly ash, sulfur, tar, wood lignin and resin, sulfate, and petroleum resin. In approximately 90 percent of present all-weather highways, asphalt is used as the binder in the main surface elements and in almost all the rest hydraulic cement is used. The main binders in the sublayers are water, lime, lime-fly ash, asphalt, and portland cement. The one promising new binder that will be available in sufficient quantity for large-scale use is sulfur, which has been used on an experimental basis in a sulfur-asphalt system and eventually may be able to be used without asphalt.

Considerable discussion concerned the fuel potential of asphalt. Because all asphalts used today contain significant quantities of chemically combined sulfur, they are unsuitable for use as a fuel without the development of technology for removing the sulfur. Therefore, many asphalts are now at least a by-product in the refining of petroleum that cannot be used for fuel. Consequently, the quantities of asphalt for transportation construction should be sufficient for the near future, provided asphalt use is optimized.

Portland cement, a most valuable binder, is also currently available in sufficient quantities for transportation construction, again provided its use is optimized. Cement is an energy-intensive product; approximately 7.5 million Btu (7912 MJ) are required to produce 1 ton (907 kg) of cement. Processes have been optimized and fuel efficiency increased by 1.6 percent in the last 2 years, despite a 2.6 percent increase in electric power consumption to meet air pollution standards (1).

2: QUALITY STANDARDS AND QUALITY CONTROL

From rather simple beginnings 5 or 6 decades ago, quality standards in transportation construction have evolved into sophisticated, complex, and time-consuming procedures. Consideration has been given solely to quality, and almost no thought has been given to energy. Today, transportation engineers are scrutinizing their quality standards and questioning whether a particular standard actually performs its intended function. Participants recognized that "first energy" like "first cost" is only the first step and that an arbitrary reduction in quality in initial design, materials selection, and construction standards could result in increased life-cycle costs of all types, including energy and service.

3: AGGREGATES AND OTHER MATERIALS

Aggregates constitute 70 to 100 percent of the solid volume of the pavement structure and thus play an important role in the optimization of materials and energy in transportation construction. According to Marek and Jones, almost 1.8 billion tons (1.5 billion metric tons) of nonmetallic construction materials (sand, gravel, crushed stone, clay, gypsum, slag, and cement) were consumed in 1974, 300 percent more than were consumed in 1950. Even with use of this magnitude, we will not run out of aggregate, for our proven reserves are all but inexhaustible. However, geographic distribution and quality often do not match requirements. The result is that hauling aggregate can consume large quantities of energy, and thus aggregate that is normally inexpensive can become quite costly.

4: EARTHWORK OR EXISTING ROADWAY PREPARATION

Since it often constitutes 30 percent or more of the construction cost, earthwork was considered to be a fruitful area for further optimization. Nature has provided a seemingly infinite variety of soils and soil problems, so the transportation engineer rightly considers each project to possess unique earthwork problems. The complexities of earthwork operations, however, should not deter their renewed examinations.

5: WASTE MATERIALS, BY-PRODUCTS, AND RECYCLED PRODUCTS

Many people believe that we are being inundated by our own waste products. Indeed, the quantities of waste materials and by-products are large, but they are relatively small when compared to the billions of tons of materials used in transportation construction each year. The disposal of waste materials costs money and energy. Materials such as aggregates cost money and energy. An optimum plan may be the use of waste products, by-products, and recycled products whenever possible in transportation facility construction.

6: PRODUCTION AND CONSTRUCTION TECHNIQUES

The energy consumed in producing materials and in constructing transportation facilities is significant. Participants agreed that there were potentials for energy savings and developed a number of recommendations.

7: NEW PRODUCTS AND PROCEDURES POST-1985

In one sense, this topic is the most important, for what is done now will largely influence activities after 1985. Changes are occurring extremely rapidly. We know our supply of fossil fuel is finite and dangerously small. Transportation, as the largest consumer of fossil fuel, is going to change drastically by 1985. How is it going to change? What effect will these changes have on transportation construction and reconstruction? What do we do now to prepare for the changes that will surely occur? Participants were in general agreement on 4 points:

1. By 1985 we will be expending most of our materials, energy, and money maintaining our transportation investment and least on new construction;
2. By 1985 we must have alternate binders to supplement asphalt and portland cement;
3. By 1985 we must have a fully integrated and cooperative transportation network in which all modes work optimally; and
4. Large research efforts are needed now if we are to be ready for 1985.

CONCLUDING REMARKS

The thoughtful ideas and suggestions emanating from the workshop will be effective only if they are implemented. That will require initiative by those individuals who are in responsible positions in transportation departments and who are willing to try them. We can learn from the turtle, who advances by sticking his neck out. To substantially reduce materials and energy used in transportation construction, we may have to adopt similar behavior.

REFERENCE

1. Cement Industry Reports Gains in Coal Conversion, Energy Efficiency. Portland Cement Association, news release, June 9, 1975.