CHAPTER EIGHT

FEDERAL PROGRAMS SUPPORTING RESEARCH ON MATERIALS FOR PUBLIC WORKS

The Federal Government directly and indirectly funds a wide range of materials-related R&D for public works, including improved materials for highways, water supply and waste-water treatment systems, dams, airports, and public buildings. Table 8-1 shows the approximate Federal expenditures on materials-related infrastructure R&D in FY86; detailed breakdowns and project lists may be found in the Appendix.

DEPARTMENT OF TRANSPORTATION

Within the Department of Transportation, the Federal Highway Administration (FHWA) is the primary sponsor of Federal R&D on highways, roads, and bridges. Directly-funded FHWA research includes both internal staff research and external contract research. Total funding for *all* types of FHWA direct R&D activities was about $30 million in FY86, including administrative expenses (employees' salaries and overhead). FHWA estimates that total highway and bridge construction, maintenance and repair R&D was $11.6 million in FY86.[24] Of this, around $2.5 million, or 22 percent, was materials-related. FHWA staff research accounts for about 15-20 percent of FHWA staff time. FHWA administrative contract research is conducted by outside engineering firms, consultants, universities, industry research organizations, and the National Bureau of Standards.

Most of FHWA'S directly-funded R&D on highway design, construction, operations, and maintenance is performed by the Office of Engineering and Highway Operations Research and

24 The FHWA also conducts research on highway safety and traffic operations.

Table 8-1

FEDERAL INFRASTRUTURE MATERIALS RESEARCH AND DEVELOPMENT EXPENDITURES
FY1986

Federal Agencies	Millions of Dollars
Department of Transportation	
Federal Highway Administration	2,5
State HP&R Program	9.5 (est.)
NCHRP	3.2
Other DOT agencies	2.0
Department of Defense	
Army Corps of Engineers	
Civil Works	9.9
Military Facilities	2.0-3,0
Other DOD	N/A*
Environmental Protection Agency	
Drinking Water	<2.0
Municipal Wastewater	<1.0
Department of Commerce	
National Bureau of Standards	
Center for Building Technology	2.4
Materials Sciences & Engineering	N/A*
National Science Foundation	
Systems Engineering	1.0-1.2
Other	N/A*
Department of the Interior	
Bureau of Reclamation	1,0
Other DOI	N/A*
Department of Agriculture	
Forest Service & other	0.2
TOTAL	35.0 - 37.o'~'~

:< No estimate provided for infrastructure-related materials R&D.

** Excludes Federal funding of Strategic Highway Research Program in the National Academy of Sciences, which could add $30-50 million annually over five years.

Development. Their major project areas include research on rigid pavements (concrete and cement) and flexible pavements (asphaltic materials), on protection of steel and other metal reinforcement and structural components from corrosion, and on protection of concrete and asphalt pavements and structures from corrosion and deterioration. Other materials R&D concentrates on the evaluation of new or different commercially available materials for construction, repair, and corrosion protection. Basic research aimed at developing new materials and materials applications for highway use is now probably less than $200,000 per year. The Office of Highway Operations also supports some experimental highway construction and pavement demonstration projects with materials components, but the approximate level of funding is not available.

Internal FHWA funding for research on paving materials, including asphalt and concrete, has been cut considerably in recent years in anticipation of the relatively high funding levels for pavement research under the Strategic Highway Research Program (described later in this chapter), and because FHWA believes that State work under the Highway Planning and Research Program (see below) is sufficient.[25] Based on project summaries provided by FHWA, OTA estimates that materials-related research within the FHWA declined from $2.7 million in FY85 to about $1.9 million in FY87. In contrast, in the mid-late 1970s FHWA direct contract research on asphalt alone was several million dollars per year. In addition, the number of FHWA staff engaged part-time in research has been declining, although there has been an increase in the number of contract research personnel at the FHWA facility in McLean, Virginia.

FHWA also oversees the distribution of Federal research funds to the States under the Highway Planning and Research Program and the National Cooperative Highway Research Program. The Highway Planning and Research Program (HP&R) is a cooperative Federal-State research program that finances State highway planning and research efforts under general FHWA

25 See for example, Federal Highway Administration, FC'P Annual Progress Report for Year Endin~ September 30, 1985, Project No: 4D, "Improved Flexible Binders".

oversight and coordination. HP&R funds are 1.5 percent of each State's share of Federal-aid highway funds, with an optional 0.5 percent available for urban highway research and planning.

Each State decides on the relative allocation of its HP&R funds to planning and research. The average distribution of HP&R funds nationwide is 20 percent for research and 80 percent for planning, with individual State research allocations ranging between 5 percent and 55 percent of State HP&R funds. However, States' definitions of "research" are very broad and often include evaluation of commercially available materials and processes for road construction specifications. FHWA figures indicate that total HP&R funds were $178 million *in* FY86 and $165 million in FY85. About 30 percent, or $47.3 million was spent on research in FY86, slightly more than the $46.1 million spent in FY85.[26] Based o$_n$ Hp&R project information, OTA estimates that materials-related research probably absorbed 10 to 20 percent of that $47.3 million.

The National Cooperative Highway Research Program (NCHRP) is coordinated by the American Association of State Highway and Transportation Officials (AASHTO), the FHWA, and the Transportation Research Board (TRB). The respective roles are: the States finance NCHRP by contributing 4.5 percent of their HP&R funds; the Transportation Research Board (TRB) administers the program with the approval of State officials; AASHTO'S Select Committee on Research chooses the research activities; and FHWA provides general oversight, and reviews contracts and the technical content of research projects. The NCHRP relies extensively on universities, research foundations, and private firms to conduct research, although there are some contracts with State personnel.

The Transportation Research Board estimates that NCHRP funds actually available for research (i.e., excluding TRB-AASHTO administrative expenses) are between $3.5 and $5.5

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26 The FHWA estimates of actual State research spending exclude State funds passed through to the National Cooperative Highway Research Program, which were $7.4 million in FY85 and $8 million in FY86.

million annually.[27] Estimates of the portion of this allocated to materials-related research vary. One TRB project manager suggested that materials research should include materials characterization as well as materials aspects of pavement performance, construction, design, maintenance, and repair. Based on this definition, he estimated that, on the average, 25 to 30 percent of NCHRP work is materials-related. Actual project figures provided by TRB to OTA suggest that materials-related projects may have totaled as much as 45 percent of total NCHRP research spending for FY85-FY87. These projects include research on: corrosion protection; the evaluation of materials additives; the performance of pavements and structures; and the development of pavement management systems, of techniques for predicting materials performance and failure, and of nondestructive evaluation methods.

The Federally Coordinated Program of Highway Research & Development (FCP) was set up in 1971 to coordinate State and Federal activities. FCP covers virtually all of the FHWA staff and contract research, and about 70 percent of State HP&R and NCHRP work.[28] The FCP categorizes State and Federal projects according to overall research goals and reports on progress and publications; it has no separate research budget.

OTA estimates that research on infrastructure materials conducted by other DOT agencies and programs probably totals around $2 million per year:[29]

- o The National Highway Traffic Safety Administration (NHTSA) researches the relation of vehicle characteristics and roadway design and construction to aGcident prevention;

27 Funds actually allocated to research vary from year tO year because of multi-Year and "phased" projects. Of $10.1 million in actual NCHRP project expenditures for FY85-87 reported to OTA by the Transportation Research Board, about $4.6 million was dedicated to materials-related projects.

28 Most of th$_e$ remaining 30 percent of Hp&R work focuses On SIXCkil local needs or n~tional problems selected independently by h'CHRP committee.

29 Transportation Research Board, A mer *ica's H i ~h wQvs:* Accelerating the Search for Innovation, Special Report 202, 1984, at pp. 36-37,

- The Urban Mass Transportation Administration (UMTA) supports some research that directly relates to street design and operation;
- The Transportation Systems Research program in Cambridge, Massachusetts conducts some materials research as part of studies funded by other DOT agencies, such as an evaluation of high-strength concretes for mass transit tunnels and structural support systems;
- The Federal Aviation Administration (FAA) sponsors some pavement-related research on airport runways that also could be applicable to highway problems; and
- The DOT Office of University Research funds highway transportation research projects through a special grant program.

DEPARTMENT OF DEFENSE

The Department of the Army-Corps of Engineers manages the second largest Federal R&D effort on infrastructure materials. This R&D supports the Corps' responsibilities for construction and maintenance of water resource projects, dams, locks, waterways, ports, flood control projects, and military facilities. The Corps spends approximately $1.6 billion annually on civil works construction, and an additional $1.4 billion on operations and maintenance. The Corps also spends about $1.5-$2 billion per year for new construction on Army installations, and around $1.8-$2 billion annually in maintenance and repair. Their annual R&D budget for *civil* works is about $30-$35 million, of which about $9.9 million is materials-related. The Corps also spends at least $2-$3 million annually on *military* R&D projects relevant to infrastructure materials.

The Army Corps of Engineers maintains a broad range of materials science and engineering R&D and technology transfer activities to support its civil and military missions. Their generic materials-related research involves materials characterization, performance evaluation of materials in use, corrosion prevention, and development of maintenance management systems and nondestructive testing methods and equipment,

Of particular interest to this survey are the Corps' special research and demonstration programs that promote the application of innovative technologies to infrastructure problems.

The Repair, Evaluation, Maintenance, and Rehabilitation Research (REMRR) Program is a six-year, $35 million effort set up to meet the need for research to meet the growing demands of the Corps' civil works. The Facilities Technology Applications Test (FTAT) Program--a five-year, $29 million effort-- focuses on transferring advances in operations, maintenance, and rehabilitation technologies from the Corps' research laboratories (see below) to Army installations through demonstration projects on energy conservation, building maintenance and repair, pavements, railroad maintenance, and environmental quality. Many of the technologies and methods selected for demonstration in the FTAT Program are derived from the Corps' military-related Base/Facility Development and Installation Support Research Programs.[30] In FY87, the Corps initiated a companion program to FTAT, the Technology Transfer Test Bed Program, to promote the application of their R&D resu ts in new construction at military installations. According to Corps' researchers, the multiple military technology transfer programs in part reflect the separate appropriations for Corps' mi itary R&D and military construction.

The Corps maintains four major research laboratories to conduct its R&D and to provide technical assistance, testing, and other analytical services for its civil and military operations. Eight smaller laboratories provide quality control, as well as detailed testing and analyses of construction and other materials, for investigations, design, and construction of specific civil and military projects. The three major laboratories that carry out infrastructure-related R&D are: the Construction Engineering Research Laboratory in Champaign, Illinois; the Waterways Experiment Station in Vicksburg, Mississippi; and the Cold Regions Research and Engineering Laboratory near Hanover, New Hampshire.

30 The Corps did not provide project lists or estimates Of FY84-FY86 funding for materials-related research with potential application to civilian public works under the military-funded Base/Facility Development and Installation Support Research Programs. Therefore, these efforts are not reflected in OTA's estimates of total R&D expenditures for those years in Table 1 and else where. OTA estimates that, in FY87, the Corps may spend from $3-$4 million on materials-related R&D under these programs in three areas: construction materials, maintenance management systems, and pavements and foundations.

The Construction Engineering Research Laboratory (CERL), which is associated with the University of Illinois, has primary responsibility for the Corps' R&D on buildings and structures and on life-cycle management of Army installations. CERL'S major materials-related research emphases are on the performance characteristics of metallic construction components (especially welding technology), and on the evaluation of coatings and other corrosion preventives. One product of CERL'S facilities management R&D was the PAVER system--a computerized pavement maintenance and management system for roads and airport runways. PAVER later was adapted for civilian use in cooperation with the American Public Works Association. CERL also does work on water and waste water treatment systems for military facilities. CERL'S research budget is approximately $40 million per year, of which about 10 percent or $4 million involves materials-related research relevant to public works.

The Waterways Experiment Station (WES) is the largest of the Corps' research laboratories. Its research activities encompass materials and techniques for construction, maintenance, and repair of pavements, waterways, dams, ports, and concrete structures, including some work on geotextiles. WES also investigates the effects of coastal and riverine processes on navigation, flood and erosion control, and coastal and offshore structures and their component materials. WES' concrete research alone is estimated at $1.2 million in FY87.

The Cold Regions Research and Engineering Lab (CRREL) focuses on the special materials, engineering, and construction problems of cold environments. CRREL'S work on pavement performance and subsoil characteristics under extreme cold and temperature variations is useful to the military services as well as to northern State highway agencies. No estimate of CRREL'S infrastructure materials R&D budget is currently available, but it is much smaller than programs at other Corps laboratories.

iMuch of The Corps' materials research is intended to support its construction and maintenance functions and is not directed primarily at the development of new materials. However, if commercially available products are not adequate for, or cannot be adapted to solve

the unique problems often encountered in Corps' facilities, researchers will develop a new product or technology. As a result of such original problem-oriented research on corrosion prevention, for example, CERL developed ceramic anodes for cathodic protection systems. These anodes are smaller, last longer, and cost less than current silicon- iron and graphite anodes. CERL licensed its discovery to a private manufacturer for use on bridges and other structures.

The Army, Navy, and Air Force fund other materials research with potential application to public works. For example, both the Navy and the Air Force operate smaller versions of the Corps' research laboratories to support their own facilities construction and maintenance programs. No estimates of total or materials-related infrastructure R&D for these programs were provided. In addition, the services have been expanding their support for materials, construction and engineering R&D at university research centers. For example, the Army funds two newly-established Centers of Excellence in Building Construction Technology at the Massachusetts Institute of Technology and the University of Illinois. These Centers may conduct research on building construction materials that are also suitable for other categories of public works. Similarly, the Air Force is funding a Center for Cement Composite Materials at the University of Illinois with a 3-year grant totaling nearly $3 million.[31] Detailed information on research at these Centers is not yet available, but they probably will represent a very small portion of DOD's research expenditures.

Finally, there is probably some spinoff potential for infrastructure materials from R&D on ultra-high-strength concretes and advanced ceramics and composites from the strategic defense initiative program and other military research. For example, work for the Air Force at the National Bureau of Standards' Center for Building Technology and elsewhere examines means of reducing porosity in concrete to improve its strength and its resistance to cracking and

[31] Chemical and Engineering News, March 30, 1987, p. 16.

to corrosive materials. The characteristics of these concretes for defense purposes (hardened structures, runways) are not sufficiently different from those of interest to highway agencies.

ENVIRONMENTAL PROTECTION AGENCY

The Environmental Protection Agency (EPA) funds R&D on drinking water quality and wastewater treatment to support its program and regulatory responsibilities under the Safe Drinking Water Act and Clean Water Act. Research funds are split between EPA's Office of Research and Development (ORD) and the regulatory programs. EPA budget figures indicate that total R&D funds for drinking water are about $13 million per year, and for wastewater treatment, about $8 million.[32] Research budgets under both programs are projected to increase slightly due to additional efforts arising from reauthorization and amendment of the Safe Drinking Water Act in 1986 and the Clean Water Act in 1987.

Under both the regulatory and ORD drinking water programs, EPA has sponsored research projects directly related to the construction, maintenance, repair, and rehabilitation of water supply systems, such as the corrosion of water pipes and ways to prevent or slow their deterioration. EPA also has studied how pipe deterioration contributes to the contamination of drinking water supplies (through leaching and erosion of contaminants such as copper, lead, lead solder, and asbestos fibers from pipes and joints), and means of prevention.

Most of EPA's water supply R&D is conducted at the EPA water research facilities in Cincinnati, Ohio. Their total FY86 drinking water research budget is about $5 million (including salaries, overhead, and extramural research). OTA estimates that expenditures for materials and infrastructure-related drinking water research were less than $2 million, including a $1 million "seed money" grant to the American Water Works Association Research Foundation. However, R&D directly related to infrastructure construction and repair has now largely been

32 These figures exclude salaries and overhead.

discontinued, leaving only a few projects with minor materials components. According to EPA research staff in Cincinnati, total infrastructure and materials-related R&D in FY87 is probably less than $0,2 million. Future research on drinking water will be directed heavily toward new rulemaking to set maximum contaminant levels or specified treatment techniques for some 80 different substances as required by the 1986 amendments to the Safe Drinking Water Act.

EPA conducts research on sewers and municipal wastewater treatment systems to support its regulatory and grant programs under the Clean Water Act. During the 1970s, EPA's Cincinnati Water Research Laboratories were extensively involved in R&D on innovative waste water treatment processes and maintenance, repair, and rehabilitation technologies. Changing Federal policies on R&D have largely transformed the municipal wastewater research program into a regulatory support organization that monitors technology developments in the private sector and overseas. Although EPA provides about $2.4 billion annually for new municipal treatment plant construction, their R&D on construction, maintenance, management, and rehabilitation of sewers and wastewater treatment systems has averaged less than !31 million annually in recent years. According to EPA research staff, almost all infrastructure and materials-related R&D projects in the municipal wastewater treatment program have now been zeroed out.

Materials-related research under EPA's wastewater programs largely arose out of work on solving specific problems, such as how to prevent corrosion and inflow and infiltration of

33 personal communications t. OTA from Robert M. Clark, Director, Drinking Water Research Division, EPA Water Engineering Research Laboratory, Cincinnati, Ohio. Detailed information on materials-related research was unavailable. Therefore, OTA's estimates of materials and infrastructure-related research include various EPA/ORD projects on water supply systems and drinking water problems that include aspects of system integrity, rehabilitation, materials, or hardware-related water contamination problems.

sewers. R&D in this area included basic research on the 1ong-term performance of materials and the mechanisms of corrosion in order to formulate appropriate corrective strategies. Past materials-related research included work on methods for repair and rehabilitation of sewer pipes, and the evaluation of new synthetic and natural fiber filters to remove contaminants during sewage treatment. However, R&D is increasingly being redirected to deal with the growing problems of toxic contaminants in wastewater treatment plants and treatment and disposal methods for sewage sludge. Moreover, both staffing and research funding are now less than half of what they were six years ago.

The Innovative/Alternative (1/A) Technology incentive set-asides under the construction grants program[35] of the Clean Water Act offer a potential market of several hundred million dollars per year for new sewage treatment technologies, but provide no funding for actual research and development. As a result, many new wastewater treatment processes are now being tested at the full plant scale rather than at bench or pilot project scale.

In addition to research done under the Clean Water Act and Safe Drinking Water Act, expanded EPA efforts in the area of hazardous wastes and toxic pollutants may have some relevance to technologies for both drinking water and wastewater treatment. EPA researchers and others noted that development of treatment technologies for removal of contaminants from leachate at Superfund sites may prove useful for water supply and wastewater treatment systerns.

[M] Corrosion, a severe problem in some areas, can lead to deterioration of sewers and their eventual collapse. Infiltration refers to the permeation of rainwater, as groundwater, into a sewerage system. Infiltration occurs through cracks in pipes, at pipe joints as settling and other movement occur, and where side-branches ("laterals") meet the pipe. Inflow is the entry of water from sources such as illegal storm drain connections, or excessive storm water entry at manhole covers. Inflow and infiltration can increase the amount (and costs) of sewage treated by as much as one third, and pose materials-related research problems that can be quite different from those presented by corrosion.

35 Innovative technologies are narrowly defined as new processes not Yet widely accepted in practice that achieve the required sewage treatment levels at lower costs than conventional technologies, and/or save energy.

DEPARTMENT OF COMMERCE

Within the Department of Commerce, the National Bureau of Standards (NBS) conducts research on infrastructure materials at the Center for Building Technology and the Institute for Materials Sciences and Engineering. Their research is directed primarily toward advancing the fundamental understanding of materials characteristics, composition, and performance; and developing standardized testing methods and equipment.

The Center for Building Technology (CBT) in Gaithersburg, Maryland focuses primarily on the study of materials that "derive their properties in the field," such as concretes, cements, and paints, as opposed to those that are fabricated off site and thus can be standardized more easily. Although direct appropriations for CBT are !$3-$4 million, they currently spend a total of about $13-$14 million annually. Over sixty percent of their funding comes from other Federal agencies (such as the Department of Energy, Federal Highway Administration, General Services Administration, the Corps of Engineers, and the Air Force). A small percentage comes from outside the Federal Government. CBT estimates that it spends about $2.4 million per year on generic materials research relevant to public works infrastructure and other aspects of construction. Their work has, in the past, made significant contributions to infrastructure construction. For example, research they conducted for the Federal Highway Administration in the early 1970s led to the development of epoxy-coated steel reinforcing bars for highway construction.

Much of CBT'S current work on concrete is aimed at deriving basic information on the interrelationships between the composition and structure of cements and concretes and their performance in the field, and at developing standardized mathematical descriptions for this information. The results of these efforts will make it possible to conduct more systematic research on concrete and cement, to develop predictive models of performance, and to communicate the results of the research more effectively.

In addition, CBT is evaluating the performance of various anti-corrosive surface coatings (mostly paints, but also epoxies and polyurethanes), and the relationship of substrate condition

and preparation to service life. Other R&D activities at the Center include earthquake resistance of materials and structures, performance of concrete structures in hostile environments, and development of nondestructive evaluation methods for new and existing structures. The Construction Materials Reference Laboratory, part of the CBT Building Materials Division, is supported and staffed by the American Society for Testing and Materials (ASTM) and AASHTO. It provides a voluntary service to assist construction materials laboratories throughout the nation in evaluating and improving the quality of standard testing procedures for primary construction materials, such as cement, asphalt, aggregates, and soils.

The Institute for Materials Sciences and Engineering (IMSE), also in Gaithersburg, houses other NBS research on infrastructure materials. The Metallurgy Division develops methods of measuring the corrosion rates of steel and other metals used in construction. The Polymer Division handles research on plastics, including polymer blends and composites; its work on plastic pipes is especially relevant for public works. The Fracture and Deformation Division provides basic engineering data needed for design through its studies of fracture and deformation strengthening of steel and other structural alloys and its failure analyses of other materials. Estimates of the level of funding of infrastructure-related materials R&D at IMSE were not available, but their total funding is about $22 million annually.

The Economic Development Administration of the Department of Commerce funds construction of local public works projects including streets, water supply systems, and wastewater treatment facilities. EDA has a modest research and technical assistance budget, but most of that is spent on planning and socioeconomic studies about economic development.

NATIONAL SCIENCE FOUNDATION

The National Science Foundation (NSF) is a major source of funding for university and other private sector research in civil and chemical engineering. Research on infrastructure materials is funded under several NSF programs. The most direct infrastructure research is carried out under the NSF Engineering Directorate's Mechanics, Structures, and Materials Engineering

Division, and Emerging and Critical Systems Engineering Division. Additional materials research is sponsored by the Mathematical and Physical Sciences Directorate's programs in ceramics, metallurgy, and polymers, and by the Materials Research Labs and Research Groups. Some water-resources research is funded within the Engineering Sciences programs on Chemical, Biochemical and Thermal Engineering, and Environmental Engineering.

Total FY87 funding for the Engineering Program is $162 million, and for mathematical and physical sciences, $464 million. Information provided by NSF indicates that materials-related infrastructure research received $1,8 million in FY85 and $0.9 million in FY86. However, OTA has only received a partial listing of the infrastructure-related research under the Engineering Program.

DEPARTMENT OF THE INTERIOR

Within the Department of the Interior, the Bureau of Reclamation constructs, operates, and maintains dams for reclaiming arid and semi-arid kinds in the Western United States. The Bureau's projects often serve multiple purposes, including municipal and industrial water supply, hydroelectric power, irrigation, water quality improvement, flood control, navigation, recreation, and fish and wildlife enhancement. The Bureau spends $600 to $700 million annually for construction and another $260 million for operations and maintenance (O&M). About 81 percent of construction and O&M costs are reimbursable through contracts with project beneficiaries, although the repayment periods may be very long.

Based on a program review document provided by the Bureau, OTA estimates that total materials-related research funding in FY86 was slightly over $1 million. The Division of Research and Laboratory services conducts most of the Bureau's public works R&D; they have an annual budget of approximately $3 million ($825,000 in materials research) and about 130 ongoing projects. Most materials projects are funded for around $100,000 over a multi-year period. Some additional materials research on concrete structures and materials, totaling about $200,000 in FY86, was conducted in the Division of Water and Land Technical Services. Re-

search sponsored by the Program Related Engineering and Scientific Studies program (PRESS), within the Bureau's Denver Engineering and Research Center, includes the performance of cement and concrete in dams and canals, corrosion prevention for metals and concrete, and materials evaluation methods. *In* addition, the Bureau and the Corps of Engineers have cooperated in several areas of research. The Bureau's R&D program undertakes some original and problem-oriented research, but, as with the Corps of Engineers, a significant share of the effort is devoted to the evaluation of available products and the development of materials specifications for Bureau projects.

Also within the Department of the Interior, both the U.S. Geological Survey (USGS) and the Bureau of Mines conduct some materials research relevant to infrastructure. The USGS maintains a research and assessment program on water resources, water quality, and water availability for surface and groundwater, which can assist in the planning and design of water resource and water supply projects. The USGS also studies the occurrence and characteristics of minerals used in construction materials. The Bureau of Mines tracks domestic and international 'mineral production and consumption. The Bureau discontinued support for its asphalt research center in Laramie, Wyoming as part of a privatization initiative; the laboratory now conducts contract research under private ownership. For many years, they also supported a modest research effort in the characteristics and uses of construction and clay materials. With their recent switch in emphasis to strategic and critical materials, however, their support for research on construction materials has been reduced substantially. Estimates of USGS and Bureau of Mines materials R&D are not available.

THE DEPARTMENT OF AGRICULTURE

The U.S. Department of Agriculture (USDA) finances construction of roads and water supply and wastewater treatment facilities under several programs. The most notable is the National Forest roads program, which builds and maintains a 320,000 mile road system and adds about 10,000 miles per year, making it the fourth largest road system in the world. Annu-

al Forest Service road-related expenditures are about $750 million. The Transportation Research Board reports that the USFS has funded a "small but productive R&D program to reduce its construct ion and maintenance costs and to improve the performance of its road system."[36] USFS expenditures for road-related R&D have been around $0.2 -$0.3 million per year. The TRB report categorized the USFS as the "central source of R&D in the U.S. for low volume roads, which are a major part of the public roads system in rural areas."

The Farmers Home Administration (FmHA) finances construction of rural water supply and wastewater treatment systems through grant and loan programs, but has no supporting research program. The Soil Conservation Service (SCS) conducts research on water and soil conservation and constructs small flood and erosion control projects. Some SCS projects may have materials components but OTA has not yet been able to identify them.

OTHER FEDERAL AGENCIES

There are a number of other Federal agencies that fund materials research that may be applicable to infrastructure, but these agencies generally do not segregate their programs or ex - penditures in such a way that infrastructure-related research can be identified easily. For example, the Department of Energy's Basic Energy Sciences Program is a major sponsor of advanced materials research in the U.S. Over $150 million was allocated to materials sciences research under this program in FY87. Some DOE-funded research on advanced ceramics (including cements and concretes) and on composites clearly has some potential application to construction of public works projects. Research in the area of energy conservation may prove extremely useful in reducing energy costs for wastewater treatment plants and for production of cements, concretes, and asphalts. OTA does not have estimates of the level of research at DOE or other agencies (such as TVA, NASA, HUD) that might be relevant to infrastructure materi-

36 Transportation Research Board, supra note 29, at p. 37.

als. However, two special short-term projects of note are worth describing here: the National Council on Public Works Improvements and the Strategic Highway Research Program.

OTHER FEDERALLY-FUNDED RESEARCH PROGRAMS

National Council on Public Works Improvement

The Public Works Improvement Act of 1984 (Public Law 98-501) created the National Council on Public Works Improvement as a Federal Advisory Commission to report to the President and the Congress on the state of the nation's infrastructure. The legislation directed the Council to analyze: the age and condition of public works; the capacity of public works to meet current and anticipated economic development; and methods used to finance the construction, rehabilitation, and maintenance of public works. While the Council initially is focusing on transportation, water resources, and waste management, the Act defines public works to include all types of infrastructure. In future reports, the council may include hospitals, schools, jails, courthouses, and space travel and telecommunications facilities.

The Council's' first report, published in September 1986, presented the results of a broad survey of public works issues and analyses in the categories of decisionmaking, technology, and economics and finance.[38] The report's preliminary conclusions On technology emphasize the promise that new materials, construction technologies, and information and communication systems hold for improving the productivity, performance, and durability of public works.

The Council will produce two additional reports by 1988 that will analyze the issues identified in the first report and suggest practical approaches to meeting future infrastructure

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37 This includes highways; streets; bridges; mass transportation facilities and equipment; resource recovery facilities; airports; airway facilities; water supply and distribution systems; waste water collection, treatment and related facilities; dams; Federally-owned buildings; docks and ports; waterways; and other facilities critical to economic development.

38 National Council on Public Works Improvement, supra note 1.

needs. In addition, the Council has commissioned a series of background papers on topics relevant to their legislative mandate. The Council is doing no research of its own on infrastructure materials.

The Strategic Highway Research Program

The recently-enacted highway bill (P.L. 100- 17) established the Strategic Highway Research Program (SHRP) as an intensive 5-year program of Federally-funded research on prob - lems affecting the nation's highways and bridges. SHRP is administered by the National Research Council.[39] Materials-related research is the major focus Of this Program. Full funding for the program has been authorized by the Congress.

Using start-up funds, SHRP has completed a two year planning and assessment process to further define projects under the six primary research areas originally identified in the Transportation Research Board report, America's Highways: Accelerating the Search for Innovation. The TRB criteria for selection of research areas included gaps in current knowledge, lack of a previous coordinated research effort, and potential for high short-term payoff from new advances. The research areas and approximate levels of funding are:

1) asphaltic materials--!$5O million,
2) pavement performance--$5O million,
3) maintenance cost-effectiveness--!$20 million,
4) concrete bridge component protection systems--$l O million,
5) cement and concrete --$ 12 million, and
6) chemical control of ice and snow--$8 million.

[39] The National Research Council is the operational arm of the Federally-chartered National Academy of Science (NAS) and National Academy of Engineering (NAE).

[40] Transportation Research Board, supra, note 29.

SHRP is administered by an executive committee, and four separate advisory committees oversee the six research areas. The four advisory committees are Asphalt, Long-term Pavement Performance, Maintenance and Snow Control, and Concrete and Bridge Components. SHRP projects will be carried out by both public and private bodies, including Federal agencies, States, universities, trade associations, and private contractors and consultants. Some research may even be conducted overseas.