



Highway Engineering - An Overview

An Online Continuing Education Course for Engineers

Course Number: T-3024

Credit: 3 Hours / 3 PDH / 3 CPD

Highway Engineering – An Overview

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I. INTRODUCTION

I.1. History of Highway Development

The earliest travel was on foot; later pack animals were used, crude sledge was developed, and simple wheeled vehicles were evolved.

The streets of Babylon were paved as early as 2000 BC. Traces of early roads have been found on the Island of Crete. Egyptians used roads to aid in building the Great Pyramid nearly 3000 years before Christ. Early civilization of Chinese, Carthaginians and Incas had also built extensive roads. In ancient world, Romans had the advanced highway system. Many of these roads were built by stone and were three or more inches in depth. Interest in road building in Europe started in late 18th century. The regime of Napoleon in France gave a great impetus to road construction, chiefly for military purposes and led to the establishment of a national system of highways in that country. At about the same time in England, Thomas Telford and John McAdam developed similar type of construction. The system developed by McAdam is still in extensive use, being the forerunner for various types of modern McAdam bases and pavements.

During the early history of American colonies, travel was primarily local in character, and rural roads were little more than trails or cleared paths through the forests. Toward the end of the 18th century, public demand led to the improvement of various roads by private enterprise. The improvements generally took the form of toll roads or 'turn pikes'. In 1806 the federal government entered the field of highway construction by authorizing construction of the National Pike or Cumberland Road. Then followed construction of the Oregon trail, the Santa Fe trail, the Mormon trail, the California trail, and the Overland trail.

In 1830, after the advent of steam locomotives, the interest in road building began to decrease. The road building activities outside the cities virtually ceased after completion of the first transcontinental railroad in 1869. By 1900 a strong demand for highways revived due to the farmers' claim for farm to market roads. During this period, state began to recognize the need for state financial aid for road construction.

After the advent of motor vehicles in large numbers in 1904, an enormous demand existed for improved highways. By 1917 all states participated in highway construction in some fashion. Early roads in USA used natural earth, planks or wood blocks, and cobblestone. After the invention of power stone crusher and steam roller, road construction used broken stone followed by concrete later. In 1893 congress established the 'Office of Road Enquiry' and participated in highway construction on a continuous basis. After World War I, federal government actively entered the field of highway construction. In 1939 the name was changed to 'Bureau of Public Roads'. In 1967 a National Department of Transportation (DOT) was established and the Bureau of Public Roads was made a part of the Federal Highway Administration (FHWA). In 1970 the name 'Bureau of Public Roads' was dropped and it was merged with the Federal Highway Administration. Federal aid for highways began with the passage of Federal Road Act of 1916. Funds appropriated under this act were apportioned to the individual states on the basis of area, population, and mileage of rural roads. States matched the federal funds in the ratio of 50:50. Federal Act of 1921 extended the principle of federal aid and required each state to designate a connected system of interstate not to exceed seven percent of total rural mileage and placed the responsibility for maintenance of these routes on the individual state.

To provide for the matching fund, several states enacted gasoline taxes in 1919. In 1934, congress authorized 1.5 percent of annual federal funds for planning surveys and other important investigations. During World War II, highway development ceased and all efforts were concentrated on national defense. Highway construction was restricted to provide access roads to military establishments. Federal-Aid- Highway Act of 1944 provided funds for highway improvements in post war years. The law also required designation of two highway systems – one was the National System of Interstate Highways and the other was one composed of the principal secondary routes (Federal Aid Secondary System). The 1952 act contained specific authorization of funds for the National System of Interstate Highways. Intensive efforts by all interested groups in 1955 and 1956 led to the passage of the Federal-Aid Highway Act of 1956. This act authorized completion of 41,000 miles of National System of Interstate and Defense Highways. By 1992, the Interstate system was virtually completed with approximately 45,500 miles.

The highway legislations of the 1960s recognized the growing transportation needs of urban areas. In 1965 Congress inaugurated a highway beautification program under which funds were provided for the control of bill boards and junkyards adjacent to highway right-of-way and for road side landscaping. The highway legislation of the 1970s reflected the desire of congress to cope with the trends of increasing urbanization, traffic congestion, environmental degradation, and shortages of fuel. The legislation established guide lines designed to ensure

that possible adverse economic, social, and environmental effects are properly considered during the planning and development of highway projects. The intent of this requirement was to make sure that consideration is given to adverse effects due to air, noise and water pollution, the displacement of citizens, farmers and businesses, and the disruption or destruction of natural resources, public facilities, community cohesion and aesthetic values. The Surface Transportation Act of 1982 was passed to address the problem of deteriorating highway infrastructure. Intermodal Surface Transportation Act of 1991 made significant changes to the ways highways were funded and administrated. The law required that the states have a statewide transportation planning process and specified the various elements that must be included in such a process.

I.2. Administrative Classification of Highways

Administrative classification is used for allocation of funds and to define the authority for planning, design, construction, maintenance, and operation of specific highways. They can be grouped into Federal-Aid Systems, State Systems, and Local Systems. The highway system designated by the Federal Highway Act of 1921 came to be known as Federal-Aid primary system. Later Federal-Aid Secondary system and the Federal-Aid Urban system were designated and made eligible for federal funds. The Intermodal Surface Transportation Act of 1991 eliminated the federal-aid systems and created the National Highway System. Each state has its own state-designated system, made up principally of arterial and collector routes of statewide importance. Local road systems have the greatest percentage of mileage of roads. Local governments include counties, townships, and municipalities. Routes traversing the country from east to west bear even numbers while those traverse from north to south bear odd numbers. Between 1950 and 1958, many toll roads or turn pikes were built. Toll roads in general were built by special authorities created by the state governments.

II. HIGHWAY ADMINISTRATION

II.1. Federal Highway Administration (FHWA)

Administration of public highways is a governmental function. The Federal Highway Administration acts as the representative of the federal government in all matters relating to public highways. It is one of the ten units in the US Department of Transportation (DOT). Secretary of Transportation, a member of the president's cabinet, has the prime responsibility in DOT.

FHWA is headed by an Administrator and a Deputy Administrator and an Executive Director serve under him. The FHWA has four resource centers that oversee state level division offices numbering 52. The FHWA administers the federal-aid highway program providing financial assistance to the states for highway construction and improvement of the efficiency of highway and traffic operations.

Financing for these roads and highways is generally on an 80% federal and 20% state basis. Federal government funds 100% for highway construction in national parks and forests, Indian reservations, and federally controlled lands. Each year congress authorizes federal funds for highway construction. The funds are apportioned among the states each year. These apportionments are distributed proportionately among the states by formulas that take into account area, population, vehicle miles traveled in each state. Each state draws up programs of projects to be built with the apportioned funds. After acceptance of the program by FHWA, the state makes detailed survey for each project and prepares plans & specifications with cost estimate which must be approved by FHWA. Then the state calls for bids and enters into contract with the lowest bidder with the approval of the FHWA. The project goes out for construction and the day-to-day supervision is done by state engineers. FHWA engineer makes periodic inspections of the site. FHWA does not dictate design standards. Most of the states follow standards developed by the Association of State Highway and Transportation Officials (AASHTO) which are endorsed by FHWA. The state makes periodic payments to the contractor and claims reimbursement from the FHWA. After the project is completed, inspected and accepted, detailed accounting of costs is made by the state and reviewed by the federal auditors. After acceptance, the federal share of funds is made to the state.

II.2. State Highway & Transportation Departments

States are responsible for planning, design, construction, and operation & maintenance of routes constructed with federal funds subject to review and approval by the FHWA. In terms of the administrative control, the state department of transportation falls in to one of the following three classes:

1. A single executive
2. A single executive with a board or commission acting in an advisory or coordinate capacity
3. A board or a commission

The single executive type of organization usually has a commission, or a director or a secretary who reports directly to the governor. The executive may be elected or appointed. A large number of state highway organizations are under the administrative control of elected or appointed boards or commissions. In most sections of the country, the county is the prevailing unit of local road administration. Larger and more populous counties have adequate engineering organizations which are on par with those of the state highway departments. Responsibility for city streets is vested with city engineer, director of public works, city manager or some similar official depending on the government structure. Street departments in larger cities have their own organizations whose duty is planning, design, construction, operation and maintenance of city streets.

II.3. Highway Finance

There are two general methods of financing highways as shown below:

1. Pay-as-you-go-method
2. Credit financing

The first method involves paying all highway improvements and the costs of operating and maintaining the highway system from current revenue. The second method involves borrowing money to pay the costs of highway improvements. The borrowed money with interest is repaid over a period of time from future income. The government makes use of its credit to borrow the money. Credit financing is accomplished through issue of bonds. A bond is a written obligation or debt instrument issued by an Agency for the purpose of borrowing funds for capital improvement projects.

Bond is classified as 'general obligation bond' and 'revenue bond'. General obligation bond is backed by the entire faith and credit of the issuing agency. Revenue bond is employed in the construction of a specific facility such as a toll road or a bridge. The bond issue is secured by the pledging of future tolls to repayment of the bonds. This is sometimes called 'limited obligation bond'. Instead of the bond being backed by the entire faith and credit of the issuing agency, if the pledging of a particular future income such as gasoline tax is made, such a bond is termed 'limited obligation bond'. Highway bonds are issued for ranging periods typically from 10 to 50 years. Two methods are adopted to 'retire' (paying back the debt) the bond. One is 'sinking fund' method and the other is 'serial method'. In sinking fund method, the entire

amount borrowed falls due at the end of the period of time that is fixed when the bonds were issued. Money required to pay the obligation when it falls due or when bonds 'mature' is provided by setting aside an annual sum toward the payment of the borrowed amount. Serial bonds are retired by periodic (annual) payments on the principal and interest. The sinking fund method is abandoned in favor of serial method.

The principal sources of revenue to fund necessary improvements to highway system are:

- a. Highway user taxes
- b. Property taxes
- c. Tolls

There are three general categories of highway user taxes and related fees, and special taxes levied by the State of Oregon on automobile operator and chauffeurs. Fees for duplicate license plates, vehicle mileage, ton-miles, passenger miles, and the special nature of these vehicles is also taken into account.

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registration taxes, registration taxes were levied first in 1919 and fees include: transfer fees, and fees computed based on total miles. The special nature of

Two types of property taxes are used:

These include

1. Ad valorem property tax
2. Special assessment tax

Special assessment tax is levied on property adjacent to a highway improvement. Ad valorem tax is primarily used by local units of government including counties, townships, incorporated places and similar administrative units. Ad valorem tax is levied on the assessed or fair value of the land and improvements located thereon or on a similar value of personal property. Special assessment is principally used in towns and cities.

Special assessment is usually made on a frontage basis rather than on the property value. Assessments are made on abutting property only or on property located on adjacent side streets and even parallel streets, depending upon the nature and amount of benefits that are expected to accrue from the proposed improvement.

Neither of these types is an important source to state governments.