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THE WIDENING FIELD FOR ENGINEERS IN HIGHWAY IMPROVEMENT
AND THEIR TRAINING FOR THIS FIELD.

(Conference on Highway Engineering Education)

Any critical period in which production, inclusive of the problems of distribution and transportation, becomes the paramount issue, awakens the public to the importance of the engineer's work, and directs its attention to the necessity for a greater supply of men trained in the various phases of the engineering profession. Just now the interest of the public must extend further. It must examine into the condition in which the education institutions now find themselves, for the purpose of providing proper support funds and enlarged facilities. There must be a recognition of the fact that in the past these institutions have exerted profound influence to advance engineering knowledge, and that there is now a demand for a greater number of technically trained men each year than these institutions can possibly prepare. There must be further recognition of the fact that a much closer correlation of the interests of those responsible for the instruction of engineers in the planning of engineering courses, and those who demand and will absorb the services of the men as they leave the institutions, is not only desirable but highly necessary. In this connection it is enlightening to follow the development of engineering courses in American colleges and universities. So many of our experiences occur in cycles that such a study may be regarded as forecasting the immediate future of engineering education, and from this view-point the history of this development rightfully lends encouragement and forms a stable foundation for an optimistic spirit in this conference in its consideration of the problem of supplying trained men to fill the demand for the field of highway development.

Undoubtedly, some of the conditions which engineering educators are now facing are the gravest within the period of their connection with educational institutions. True, also, is the lack of a sufficient number of trained men in all of the different branches of the profession, and in all of its different grades. Still, these are public questions, and in the past it has always seemed to require grave issues to direct the attention of the American people toward the causes and to stimulate their activity in removing these causes and providing the proper relief. So we may have faith that satisfactory progress will be made in overcoming the adverse conditions which exist today if proper attention is given these matters by those in a position to give the public correct information.

The first technical school, Rensselaer Polytechnic Institute, was founded in 1824. This was the only school of its kind for nearly a quarter of a century, until 1847, when Harvard established the Lawrence Scientific School, and Yale the Sheffield Scientific School. The University of Michigan also established the same year a course in civil engineering. Until the Civil War there were no other schools of this character. In 1862, however, Congress enacted the Morrill Land Grant Act providing, through grants of public lands, for the endowment of schools to teach agriculture and the mechanic arts. This Act immediately stimulated the establishment of technical schools, and from a total of four in 1860 the number increased to 70 by 1872 and to 85 by 1880. There are now 126 institutions providing engineering courses, 46 of which are land grant colleges operating under the provisions of the Morrill Land Grant Act. In addition to these there are

43 other institutions that give some engineering instruction.

In the 5-year period 1911-1915, it is estimated that 17000 engineers graduated, an average rate of 3400 per year. During the previous decade the average number graduated per year was approximately 2100. The increase in the number of graduates per year during the present period will not be so apparent until the graduation of the classes which are in their freshman year now. Just what this increase will be is extremely difficult to estimate because of the high percentage of students who dropped out of college between their freshman and senior years. Based on past experience of some of the leading engineering schools this total is estimated at not more than 5500. It must be remembered that even this number of engineering graduates will not be available until 1923, that the number is likely to be much smaller for this year and the two years following, and that these men will be claimed by all phases of engineering and particularly by the industries.

The four general branches of engineering, - civil, mechanical, mining and electrical, - have developed a large number of specialized phases, training in which is offered the student at the different colleges. As illustrative of this tendency, instruction is given in the following, as well as many other, fields of engineering: - chemical, sanitary, metallurgical, railroad, marine, cement, electro-chemical, textile, automobile, aeronautical, ceramic, highway, agricultural and engineering administration. One of the best known schools offers at least fifteen specialized courses.

It will be noted that the greater number of these specialized courses have a direct relationship to the industries, and in this fact apparently lies the crux of the present situation as far as the future supply of highway engineers for the public service is concerned.

As was true after the Civil War, so now a great demand has come suddenly for large numbers of technically trained men, and it must be remembered that the high school graduate is, under the plan of education generally followed, four years distant from his availability to meet the demands. Industry of all classes has been so tremendously stimulated by the demand for increased industrial production, and so well supported by increased prices, that the possibilities for advancement in the industrial engineering fields offered the young man when choosing his college course are alluring. Every organization is naturally selfish in its desires to secure the best men, and the industries should not be accused of a greater degree of selfishness than other organizations who require men technically trained, but industry has been more alert in offering a tempting field than the public and semi-public organizations such as the railroads, Federal and State governmental engineering departments, and like organizations.

It seems well within the province of this conference, therefore, which is interested in the relationship of the engineer to the highway program, and the supplying of technically trained men to meet the present and increasing demands in this field, to take account of the widening field of opportunity offered the man who intends to follow some engineering profession, to plan the proper methods by which a just and sufficient proportion of young men may be constantly drawn into the highway field, and to consider modification of present methods or adoption of new methods to make the engineering student or graduate more quickly useful and more immediately available for responsible positions.

Enlargement of Highway Program.

It is not necessary to analyze the causes for the enlargement of the highway program. It is sufficient for the purposes of this conference to point out that the present sentiment for highway improvement is founded upon the sure basis of a direct interest in highway improvement on the part of a very considerable percentage of our entire population, and that percentage is increasing rapidly. This has been brought about, as is well known, by the rapid increase in the use of the passenger car and the more recent freight-carrying motor truck. The expenditures for highway improvement are increasing at a remarkable rate, as shown by the following schedule.

Total Expenditures for Roads by Years in the United States

Year	Total
1916	\$272,634,413
1917	279,915,332
1918	286,098,192
1919 (estimated)	303,670,105
1920 (estimated available for expenditure)	783,000,000

The tremendous increase from the total estimated expenditure in 1919 of approximately 303 millions of dollars to the estimated amount available for the present year of more than 600 millions is in itself indicative of the widening field of opportunity for the technically trained engineer or the young man who is seeking to choose a profession offering wide opportunity. It is, of course, certain that the expenditures this year will fall far under the estimated funds available, due to the economic handicaps which have been placed upon production of highways through the lack of railway transportation, material supplies, contractors' organizations and labor, as well as the developing limitations of credit. This expenditure, because of these handicaps, may equal no more than fifty per cent of the amounts appropriated or authorized by the public, yet, even so, the supply of engineers necessary to carry out this program averages this year, from estimates furnished by the State highway departments of thirty-six States, twenty-three per cent less than the State requirements, which undoubtedly means that the more local subdivisions, such as counties, towns and cities, will show a considerably greater percentage of deficiency in the engineering forces reasonably required, because the larger engineering organizations, including the industries, have recruited many men from these sources.

Extension of Engineering Control of Expenditures.

While the greatly increased sums for highway improvement are indicative of the greater field for engineers, the increasing importance of the engineer in relation to the highway improvement program is

perhaps best illustrated by the progress which has been made recently in bringing highway expenditures under engineering control. The following schedule shows the rapid progress which is being made in this direction.

Year	Under Control State highway Dept.	Locally but not under S.H.D.	Per cent under Hwy. Dept. Control
1916	\$74,495,554.29	\$198,138,559	27
1917	98,179,332.11	181,736,000	35
1918	117,285,267.82	168,812,925	41
1919	132,670,105*	160,000,000	46
1920	633,000,000**	150,000,000	81

*Estimated

**Estimated available

If, through the economic limitations before noted, the expenditures for 1920 are limited to no more than 50% of the funds available through State and Federal sources, and the local expenditures are maintained at the estimated figure, the proportion of funds spent under engineering control will still be more than sixty per cent of the total funds. The tendency of the times to place all expenditures under engineering control is, however, much more correctly shown by the 76% than by any smaller percentage. This tendency is keeping pace with the growth in the demand for improved highways, and the financial support for this purpose. The fact of the growth of engineering control is further emphasized by the large mileage of highways built each year, even during the past three years while highway construction has been so seriously curtailed. The estimates for highways of all types built under engineering control is shown in the following schedule.

**Total Mileages Built by State Highway
Departments Under Engineering
Control**

Year	Total To Date	Per cent of Total Mileage of Nation	
1916	16,160	68,937	2.8%
1917	11,996	80,933	3.2%
1918	11,944	92,877	3.7%

There is a total of approximately 214,000 miles of highways on the State systems which have been chosen for improvement under State direction, or approximately 8 1/2% of the total mileage of the nation. The State systems vary from 1 to 17% of the total mileage of the several States. Perhaps the most indicative figure as pointing the way to the future importance of the State and Federal departments is shown by the increase in the mileage of highways maintained under engineering control as shown by the following schedule.

Total Miles Maintained by State Highway Dept.

Year	Mileage	Per cent Total of Mileage of Nation
1916	75,311	3.0%
1917	181,391	7.3%
1918	203,556	8.1%

From this evidence it is apparent, then, that the field for engineers in highway improvement is rapidly widening because of the demands for highway improvement followed by the appropriation of large sums for this purpose, and that the prevailing tendency of the times is to bring the construction and maintenance of highway improvements under engineering jurisdiction. Already some of the State highway departments are planning for the definite assumption of engineering control of roads which are of no more than local importance in the State. In other words, we are progressing rapidly from a highly decentralized control of highways to definitely organized systems of engineering control of all the highways from the most important to those serving only communities. From this fact follows this question, whose responsibility shall it be to direct the attention of young men toward this field and induce them to follow highway engineering as a profession when so many other splendid opportunities are open?

Supplying the Demand for Trained Men.

Up to the present time little or no attention has been given by the public or semi-public organizations which need large numbers of engineers toward directing young men into their respective fields. Apparently the supply has been equal to the demand, and little concern has been felt. This fact is now changed. The best illustration is the status of railroad engineering, from which students and graduates have turned with decision. It is reported that one well known special railway engineering course has a total of four students, all foreigners.

But consider the case of the educational institutions, which we are calling upon to train engineers. Under war conditions the teaching staffs were badly disorganized. Last year there was a tremendous influx of new students, and the appropriations have in general been far less than the enlarged needs. Salary budgets have not been revised to meet the competition of industrial engineering organizations, with the consequent loss of very many of the best qualified professors and instructors.

The instructor who, during pre-war time, has taught a specialized course in some particular phase of engineering such as highway engineering, is called upon to go into general teaching, or to spread his activities over a far greater number of students than he can possibly give proper attention. Educational institutions have necessarily given up their building programs in order to hold their teaching staffs together, while the additional room is so seriously needed. Our institutions are suffering from an unforeseen expansion which they cannot capitalize, to provide funds, as in the case of the industries, and a condition has

resulted which the public must understand and provide for. That our educational institutions cannot be neglected is a fundamental creed with the greater part of our citizenship, but the present conditions must be understood and given the proper publicity. It may be remarked in passing that this general condition is not peculiar to the institutions of higher education, but extends all down through the whole educational system.

It has been noted that inroads have been made upon the supply of engineers by industries, but it should be added that the State highway departments have responded much more quickly than has the Federal Government or the management of the educational institutions or the railroads, to the necessity of increased compensation to the engineers. The Reclassification Commission which was appointed to make a study of conditions within the Federal Government and make salary recommendations for all Federal employees, have classified the engineering service of the Government into seven divisions, - five of professional and two of lower grades. The following schedule shows the comparison of salaries in the Bureau of Public Roads in 1919 as compared with those in various States and those recommended by the Reclassification Commission, grouped under these several divisions.

Rank	Bureau of Public Roads Both Office and Field Exclusive of Bonus			Compensation Various States* Reclassification Basis			Recommended by Reclassification		
	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.
Senior Engineer	\$4500	\$4500	\$4500	\$5000	\$7150	\$610,000	\$-----	\$-----	\$-----
Associate Engineer	2500	3641	4000	2820	4300	5,000	4140	4590	5040
Assistant Engineer	2280	2656	3240	2200	4100	6,000	3240	3540	3840
Junior Engineer	1560	2141	3000	2100	2635	3,300	2400	2700	3000
Civil Engineer Aid	950	1537	2100	900	1835	3,060	1800	1980	2160
Junior Engineer Aid	720	860	1080	800	1043	2,080	1200	1500	1800
Copyist	480	767	1080	480	915	1,500	840	1020	1200
	540	760	1080	---	1200	---	1080	1170	1260

*Mass., Wis., N.Y., Del., Md., Mich., Pa., Cal., Tex., Iowa, Ill., Ind., N.J., Ohio, - 14 States.

From these it will be noted that in the fourteen typical States having well organized highway departments, the salaries are higher than those recommended by the Reclassification Commission, and very much higher than those now paid by the Bureau of Public Roads. But even this schedule is lower than the recommendations of the American Association of Engineers or the Engineering Council. The recommendations of this Association are shown in the following schedule:

Rank	Compensation	
	Min.	Max.
Senior	\$8,000	\$15,000
Engineer	4,000	10,000
Associate	3,600	5,000
Assistant	2,400	4,000
Junior	1,800	2,400
Engr. Aid Draftsman	1,800	2,400
Jr. Engr. Aid.	1,200	1,500
Copyist	1,800	2,400

From this evidence it is clear that in order to interest young men in highway engineering, and in order to secure and retain the engineering staffs necessary to provide proper training in the educational institutions in this profession, the salaries now paid to engineers must be very materially increased.

As indicating the number of engineers that are now engaged in highway work, there is a total of 312 employed by the Bureau of Public Roads at the Washington headquarters and in the field. Thirty-six States report the following totals:

Number employed by State highway departments	3939
Number with county highway organizations	1909
Number with city organizations	1200
Highway engineers outside of above classes	519

These totals are divided into classes as follows:

Those above Division Engineer or similar grade	381
Division Engineers or similar grade	903
Resident Engineers or similar grade	1995
Grade below Resident Engineer	3952
Unclassified	466

It is not presumed that these figures are absolutely correct, but they are indicative of the large number of engineers that are needed in the highway field. The additional which will be required for the next decade are estimated to average from 9 to 12 per cent per year, but it is more than probable that this percentage is far short of the actual percentage that will be required.

Responsibility of Engineering Organizations.

It can hardly be expected that young men in sufficient numbers will enter the field of highway engineering unless they have knowledge of the field ahead, nor is it fair to leave the colleges unaided to develop these men as fast as they will be required. There is a large duty in both these respects which must be assumed by the engineering organizations who wish to use these men. Reference is made particularly to the Federal Bureau of Public Roads, the State highway departments, and similar organizations. Furthermore, our ideals of engineering education were brought into this country from abroad, and the teaching of applied science has in general been founded upon the theory that the student should first learn the theory and later the application. Undoubtedly, a canvass of the executives in charge of the high-

way organizations of today will bring out the fact that they have fewer problems of theory and design to meet than of production organization and supervision.

It is the duty of these executives to lay before the heads of the educational institutions the necessity for broader training of highway engineers along the lines of the economics of highway engineering as well as in some of the humanities. Every highway department comes closely in contact with the public and has need of men who not only understand the problems underlying the administration of highway organizations and of highway development, but who can present these matters convincingly to the public, without whose favorable support the work of the highway organization cannot be successful. The lack of engineers who possess this training has been one of the most serious handicaps to the highway organization.

Fortunately, many highway departments have already played an active part in the development of highway engineering as a profession. To Dean Shaler of the Lawrence Scientific College of Harvard University, may be credited a very large share in the early teaching and stimulation of real engineering as applied to highway construction and maintenance. The influence of the Massachusetts Highway Commission, of which he was one of the first members, has had a very considerable influence in the development of highway engineering to the position which it occupies today. This fact seems indicative of the responsibilities which devolve upon the highway departments of other States in the future. There must be a close coordination and cooperation between the highway organizations and the educational institutions, much closer than has prevailed in the past. As concrete examples of the possibilities for advancement which are inherent in such a relationship are the following suggestions.

First, if the college semesters can be so arranged that students in the various years of the college courses can be placed in appropriate positions for the summer work with the highway organizations. By advancement, from year to year, to positions of greater responsibility, they not only are better prepared to meet the problems which are now paramount with highway executives because of their knowledge of the organization in all of the different classes, but they will more surely connect up their theory with its practical applications. Thus, both the highway departments and the educational institutions will function better in producing capable engineers.

Second, such a relationship will awaken from the start an interest of the student in highway engineering which will prevent his dropping out in his undergraduate years or turning to other courses.

Third, a close contact of the teaching staff with the highway organizations will prove of great mutual benefit.

Fourth, the engineering organizations should assume responsibilities for lectures and other services in the class room that the students may be constantly brought in connection with the active work.

Fifth, the research work which is of the utmost importance and necessary to every engineering organization, should be closely coupled with the work along similar lines of the educational institutions.

Finally, in the production of highway engineers, there is nothing more valuable than the short courses conducted annually which should be a product of the educational institutions and the highway organizations.

It is impossible to cram into four years of a student's life all of the technical information that he will need. It is probable that there is too much of an attempt toward this end now, and that the more highly specialized subjects should be left for post graduate study. The short courses should by all means be developed, and could well be made a part of the year's work for the highway engineering organizations to attend at least a short period of instruction annually.

These short courses should be of two general classes, first, those for the instruction of graduate engineers for the purpose of keeping them constantly in touch with the rapid developments in the field of highway engineering and for the purpose of preparing them for highly specialized technical work, especially along research lines, and second, those for the instruction along more popular lines for the benefit of public officials or those occupying positions of lesser technical importance in the organization. Practically all highway organizations work through or with public officials who are not technically trained, and who may be impatient of technical limitations and theoretical niceties. The short course along more popular lines offers the surest way to connect in a harmonious relationship the theoretical and practical minds. The great success which has been attained by many short courses of this latter character has accented their importance as a means of bringing highway departments, public officials, contractors and through them the public in general, into closer cooperation, which is the key to the solution of the most difficult problems of highway administration.