*Maintenance of Berms.* I feel it important to add that it is very desirable to plant low-growing grasses which form heavy sods, yet which are not objectionable to the property adjoining the highway A great amount of favorable publicity can be created for the various highway departments if they will work in close cooperation with their State Departments of Agriculture with respect to choice and selection of grass seed. I concur in the committee's report as to the desirability of sodding the berms and slopes, especially through rural sections.

Where pavements are narrow or traffic is heavy, it is often impossible to keep sod growing. Under such conditions it is necessary to cover the shoulder or berm with stone or gravel Under such conditions I believe it will be found quite desirable to bind this material in place by use of bitumen The proper maintenance of the berm, particularly adjacent to the edge of the pavement, is important as a safety measure

In many sections of the country, where topography is rough or rolling and the soils are easily eroded, the question of preventing excessive erosion of the side ditches is a serious problem It appears that this question might offer an interesting field for research

## REPORT ON CULVERT INVESTIGATION

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Further consideration has been given to the possibility of outlining a method of rating small drainage structures for use in arriving at the economic values of various types A small additional amount of field work has been done, for the purpose of comparing various suggested rating schemes, and as a basis for discussion of the various factors involved

The principal conclusions at this stage of the investigation are as follows:

1 In order to assign a numerical rating to a structure, which in connection with the age will indicate the probable future life, there must be evidence of continuous progressive deterioration
2 Small drainage structures are divided into two general types which must be separately considered These are flexible type and rigid type culverts.

3. Flexible type culverts—that is, those that deflect under load and thus build up side support to resist the exterior load—practically always come to ultimate structural failure through deterioration of the material of the culvert barrel Corrugated metal is the only instance of this type thus far considered
4 Rigid type culverts—that is, those that resist loads through structural strength—are generally retired from service through collapse as a structure. In this case deterioration of material may or may not contribute to the ultimate result This type includes monolithic concrete, concrete pipe, clay pipe, and cast iron pipe
5 In the case of corrugated metal culverts, the various stages of progressive deterioration are quite definite Therefore, a numerical rating can be assigned to individual structures that will have a relation to age and probable length of life
6 Evidence of progressive deterioration is not so clearly apparent in the case of rigid type culverts, and the committee is unable without further extensive investigation to formulate a method for rating such structures Structural defects are usually due not to inherent characteristics of the culvert type, but to faulty design or installation, or both The committee has records from personal observation of rigid type culverts having serious structural defects that have been in such condition without appreciable change for 19 years, also records of culverts that have been in perfect condition for the same length of time Ratings made on such structures at any time during the 19 years would have led to erroneous conclusions It is our opinion that such conditions are the rule and not the exception Study of the data available through the investigations of a number of state highway departments may disclose the proper basis for the rating of such structures Until such study can be made, the committee will not have any recommendation to make
7. Study should be made of the possibility of correlating the ratings derived under varying conditions by using a reduction factor based upon the intensity of the force causing the deterioration of the structure In this way it may be possible to reduce culvert performance under widely varying natural conditions to a common basis

## PROPOSED TENTATIVE RATING SCHEDULE FOR CORRUGATED METAL CULVERTS

The rating scheme herein suggested for corrugated metal culverts is based upon the following primary considerations.

1. There are three periods in the life of the barrel of the culvert which should be considered in outlining a rating method.
   (a) The condition in which the barrel has been practically unaffected.
   (b to k) Varying stages of deterioration of the barrel of the culvert.
   (l) The condition in which there is no assurance of continued life, or in which the culvert can no longer be considered a permanent structure In these reports this condition is called "Technical Failure"
2. In the case of corrugated metal culverts failure practically always occurs through deterioration of the metal of the culvert barrel itself The rate of this deterioration is practically unaffected by the condition of the culvert from a structural standpoint Included under structural condition are such items as, deflection, alignment, condition of joints and seams, etc

   After the material has reached the point of "Technical Failure" the structural condition may have an effect upon the remaining period that the culvert may continue to function. In some rating methods that have been used, attempt has been made to estimate the length of this probable continued period of usefulness by assigning a rating to the structural condition of the culvert as well as to the material condition The two ratings are then combined by means of an empirical formula to have the effect of slightly increasing the life that might be expected from the material rating alone The rating schedule suggested herein does not modify the material rating in this way, for the following reasons:
   (a) It is our opinion that the condition of "Technical Failure," or zero rating of the barrel is a more definite end point upon which to base comparisons of performance
   (b) It is our opinion that the additional life expectancy derived from composite structural and material rating is generally so small as to be within the probable limits of observational error
   (c) It is our opinion that the simplicity of the proposed rating schedule will tend to encourage more extensive use

Culverts having reached " Technical Failure " " l," should be given a rating of zero Culverts in " a " (unaffected) should be given a rating of 100, but should not be used in predicting life expectancies since progressive deterioration has not yet begun Owing to the slight visible evidence of deterioration for ratings of from 90 to 100, life expectancies based upon these ratings will not be so reliable as those based upon lower ratings Ratings in this stage " b " should therefore be used with caution

This classification is offered as tentative and is of course subject to change with further study Furthermore, individual users may find it desirable to make modifications to better suit local conditions

TABLE 1

RATING SCHEDULE

CORRUGATED METAL PIPE CULVERTS

| Stage | Condition of barrel | Rating |
|---|---|---|
| a | Barrel material unaffected | 100 |
| b | Spelter coating intact Crystal outlines visible though dim | 90 to 100 |
| c | Spelter coating intact but dull appearance Crystal outlines obliterated White zinc oxide generally distributed over surface | 80 to 90 |
| d | Spelter coating perforated on invert Dark discoloration of affected area The discoloration may be apparent though the pits are either invisible or not entirely through to base metal | 70 to 80 |
| e | Spelter coating perforated on invert and rust discoloration of the affected area Rust discoloration may be apparent though pits are invisible Base metal rusting in the visible pits through spelter coating | 60 to 70 |
| f | Spelter coating gone, nearly gone and gone in spots on invert Base metal oxide in form of thin tight rust, soft light rust, or small soft nodules | 50 to 60 |
| g | Spelter gone on invert Base metal oxide and precipitate from hydraulic traffic lightly incrusted Light warty or nodular growth | 40 to 50 |
| h | Spelter coating gone on invert Base metal oxide and precipitate from hydraulic traffic heavily incrusted Heavy warty or nodular growth | 30 to 40 |
| i | Spelter coating gone on invert Base metal thin and easily bent or broken | 20 to 30 |
| k | Spelter coating gone on invert Base metal perforated | 10 to 20 |
| l | Base metal gone on invert | 0 |

ECONOMIC VALUE OF SMALL DRAINAGE STRUCTURES

*Use of Rating.* The primary objective of field inspection of small drainage structures is the determination of the probable normal life of the different types under various prevailing conditions It will take the examination of many thousands of structures to accomplish this In the meanwhile the rating, being some function of the probable life of the culvert, may be of value in making comparisons of different structures subjected to similar conditions. Comparative expectancy of future life may be computed as follows.

$U =$ Unit deterioration (per year).
$A =$ Age since installation
$R =$ Rating
$E =$ Expectancy in years

$$U = \frac{100 - R}{A}, \qquad E = \frac{100}{U}.$$

To determine average expectancy for a group of structures average the values of $U$ for all the culverts and use in computing the average value for $E$.

Culverts in stage "a" cannot be used to predict average expectancies, but such culverts should be shown in the results of a field inspection in a separate paragraph as so many culverts of such and such average age serving under such and such conditions, with no apparent deterioration

It must be borne in mind that the expectancy given by the foregoing rating schedule cannot be considered, in the present state of our knowledge, to be more than an estimate of the future duration of the structure, for the reason that we do not know as yet anything about the rate at which deterioration proceeds. This formula merely assumes that deterioration proceeds at a uniform rate, which may or may not be true In fact, it seems probable that the deterioration may proceed at an accelerating rate which may be very different for the various types of structures When further investigations enable us to include a rate factor in the expectancy formula, much more valuable comparisons can be made.

*Comparative Annual Cost.* Having the comparative life expectancy of two or more types of culverts, a comparative annual cost may be estimated as follows:

Computed by the following formula:

$$C = IR + (E - S)\, f;$$

in which

$C =$ Annual cost of the structure.
$I =$ Initial cost of the structure.
$R =$ Interest rate.
$E =$ Estimated replacement cost.
$S =$ Salvage value.
$f =$ The annual deposit that will accumulate $1.00 in a period equal to the economic life of the structure with interest at $R$ per cent compounded annually

Further investigation is needed to be able to define the term "economic life," but for the present, we would suggest the use of the length of time it has taken the culvert to reach the status of "Technical Failure" In making comparisons by the annual cost method, it must be remembered that initial cost and replacement cost will vary materially with the height of the fill and that therefore only culverts in corresponding conditions should be compared Further investigation and study should make it possible to develop methods of reducing all of the structures to a common comparative basis