APPENDIX – A

TWO-LANE RURAL ROADS

ELEMENTS OF DESIGN

CREST VERTICAL CURVES

1. Two-lane Rural Roads

1.1 Introduction

The definition of rural area can be derived from the definition of urban areas. Officially, an urban area has a population more than 5,000 within the boundaries set by state or the local government. Rural areas are those areas outside the boundaries of urban areas.

The roads making up the functional systems differ for urban and rural areas. The hierarchy of the functional system consists of principal arterials (for main movement), minor arterials (distributors), collectors, and local roads and streets. In rural areas, there are relatively more collectors with further functional subdivisions of the collector category.

1.2 Functional Systems for Rural Areas
Rural roads consist of facilities outside of urban areas. The names provided for the recognizable systems are principal arterioles (roads), minor arterials (roads), major and minor collectors (roads), and local roads.

### 1.3 Rural Principal Arterial System

The rural principal arterial system consist of a network of routes with the following service characteristics:

1. Corridor movement with trip length and density suitable for substantial statewide or interstate travel.

2. Movements between all, or virtually all, urban areas with populations over 50,000 and a large majority of those with population over 25,000.

3. Integrated movement without stub connections except where unusual geographic or traffic flow conditions dictate otherwise (international boundary connections or connection to coastal cities)
In the more densely populated states, this class of highway includes most (but not all) heavily traveled routes that might warrant multilane improvements; in the majority of states, the principal arterial system includes most existing rural freeways. The principal arterial system is stratified into two design types: freeways and other principal arterials.

1.4 Rural Minor Arterial System

The rural minor arterial systems, in conjunction with the rural principal arterial system, forms a network with the following service characteristics:

1. Linkage cities, larger towns, and other traffic generators (such as major resort areas) that are capable of attracting travel over similarly long distances.

2. Integrated interstate and intercounty service.

3. Internal spacing consistent with population density, so that all developed areas of the state are within reasonable distances of arterial highways.

4. Corridor movements consistent with items (1) through (3) with trip lengths and travel densities greater than those predominantly served by rural collectors or local systems.
Minor arterials therefore constitute routes, the design for which should be expected to provide for relatively high travel speeds and minimum interference to through movement.

1.5 Rural Collector System

The rural collector routes generally serve travel of primarily intracounty rather than statewide importance and constitute those routes on which (regardless of traffic volume) predominant travel distances are shorter than arterial routes. Consequently, more moderate speeds may be typical. To define rural collectors more clearly, this system is subclassified according to the following criteria:

- **Major Collectors Roads:** These routes (1) serve county seats not on arterial routes, larger towns not directly served by the higher systems and other traffic generators of equivalent intracounty importance, such as consolidated schools, shipping points, county parks, and important mining and agricultural areas: (2) link these places with nearby larger towns or cities, or with routes of higher classifications; and (3) serve more important intracounty travel corridors.

- **Minor Collector Roads:** These routes should (1) be spaced at intervals consistent with population density to accumulate traffic from local roads and bring all developed areas within reasonable distances of collector roads, (2) provide service to the remaining smaller communities, and (3) link the locally important traffic generators with their rural hinterland.
1.6 Rural Local Road System

The rural local road system, in comparison to collectors and arterial systems primarily provides access to land adjacent to the collector network and serves travel over relatively short distances. The local road system constitutes all rural roads not classified as principal arterials, minor arterials, or collector roads.

1.7 Extent of Rural Systems

The functional criteria for road systems have been expressed here primarily in qualitative rather than quantitative terms. Because of varying geographic conditions (like population densities, spacing between and size of cities, and densities and pattern of road networks), criteria on sizes of population centers, trip lengths, traffic volume, and route spacing do not apply to all systems in all states. However, the results of classification studies conducted in many states show considerable consistency in the relative extent of functional systems.

Highway systems developed by using these criteria are generally expected to fall within the percentage ranges shown in table below. The higher values of the ranges given in table apply to states having less extensive total road networks relative to population
density. In states having more extensive total road networks relative to population density, the lower values are applicable. The range of percentages of rural collectors represents the total length of both major and minor collector roads and applies to the statewide rural roadway totals.

<table>
<thead>
<tr>
<th>Systems</th>
<th>Percentage of Total Rural Roads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal Arterial System</td>
<td>2-4</td>
</tr>
<tr>
<td>Principal Arterial + Minor Arterial System</td>
<td>6-12</td>
</tr>
<tr>
<td>Collector Roads</td>
<td>20-25</td>
</tr>
<tr>
<td>Local Road System</td>
<td>65-75</td>
</tr>
</tbody>
</table>

Table-A.1

2. The Elements of Design

2.1 Sight Distance General Overview

The ability to see ahead is of the utmost importance in the safe and efficient operation of a vehicle on a highway. The path and speed of motor vehicles on highways and streets are subject to the control of drivers whose ability, training, and experience are quite varied. For safety on highways, the designer must provide sight distance of sufficient length that driver can control the operation of their vehicles to avoid striking an
unexpected object on the traveled way. Certain two-lane highways should also have sufficient sight distance to enable drivers to occupy the opposing traffic lane for passing overtaken vehicles without risk of accident. Two-lane rural highways should generally provide such passing sight distance at frequent intervals and for substantial portion of their length. Conversely, it normally is of little practical value to provide passing sight distance on two-lane urban streets or arterials.

Sight distance is discussed in four steps:

1. The distance required for stopping,

2. The distance required for the passing of overtaken vehicle,

3. The distances needed for decision at complex locations,

4. The criteria for measuring these distances for use in design.

The design of alignment and profile to provide these distances and to meet these criteria will be described in this section.
2.2 Stopping Sight Distance

Sight distance is the length of roadway ahead visible to the driver. The minimum sight distance available on a roadway should be sufficiently long to enable a vehicle travelling at or near the design speed to stop before reaching a stationary object in its path. Although greater length is desirable, sight distance at every point along the highway should be at least that required for a below-average operator or vehicle to stop in this distance.

Stopping sight distance is the sum of two distances: the distance traversed by the vehicle from the instant the driver sights an object necessitating a stop to the instant the brakes are applied and the distance required to stop the vehicle from the instant brake application begins. These are referred to as brake reaction distance and braking distance, respectively.

2.3 Brake Reaction Time

Brake reaction time is the interval between the instant that the driver recognizes the existence of an object or hazard on the roadway ahead and the instant that the driver actually applies the brakes. This interval includes the time required to make decision that a stop is necessary. Under certain conditions denoted by flares or flashing lights, operators accomplish these tasks almost instantly. Under most other conditions the
operator must subconsciously associate the object ahead with stationary objects adjacent to the roadway, such as walls, fences, trees, poles or bridges, to determine that the object is also stationary or moving. These determinations take time, the amount of which varies considerably depending on the distance to the object, acuity of the operator, the natural rapidity with which the driver reacts, visibility, the type and the condition of the roadway, and the type and condition of the hazard. Vehicle speed and the roadway environment also are the effecting factors in reaction time. Under normal conditions, an operator travelling at or near the design speed is more alert than one travelling at slower speed.

In determination of sight distance for design, the reaction time should be larger than the average for all drivers under normal conditions. It should be large enough to include the reaction time required for nearly all drivers under most highway conditions. For approximately ninety percent of the drivers, a reaction time of 2.5 second is found to be adequate.

2.4 Braking Distance

The approximate braking distance of a vehicle on a level roadway may be determined by the following standard formula:
\[ V^2 \]

\[
d = \frac{V^2}{254f} \quad \text{(metric system)}
\]

\[
d = \frac{V^2}{30f} \quad \text{(U.S. units)} \quad \text{(A-1)}
\]

where

\[
d = \text{braking distance (meters)}
\]

\[
V = \text{velocity (km/hr)}
\]

\[
f = \text{coefficient of friction between tires and roadway}
\]

It is assumed that the friction force is uniform throughout the braking period. This is not strictly true; it varies as some power of the velocity. Other physical factors affecting the coefficient of friction at the condition and the pressure of the tires, type and condition of surface, climate conditions such as rain, snow, and ice. Friction factor for skidding are assumed to vary from 0.60 at 30 mph to 0.55 at 70 mph for dry pavements. For wet pavements these values are much lower. Recommended minimum stopping sight distances in U.S. units are shown in Table-A.2