Transportation Engineering Lab CE29003

A Rural Highway Location and Design Problem

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Due Date: **Thursday, 06th September 2018**

I) OBJECTIVE

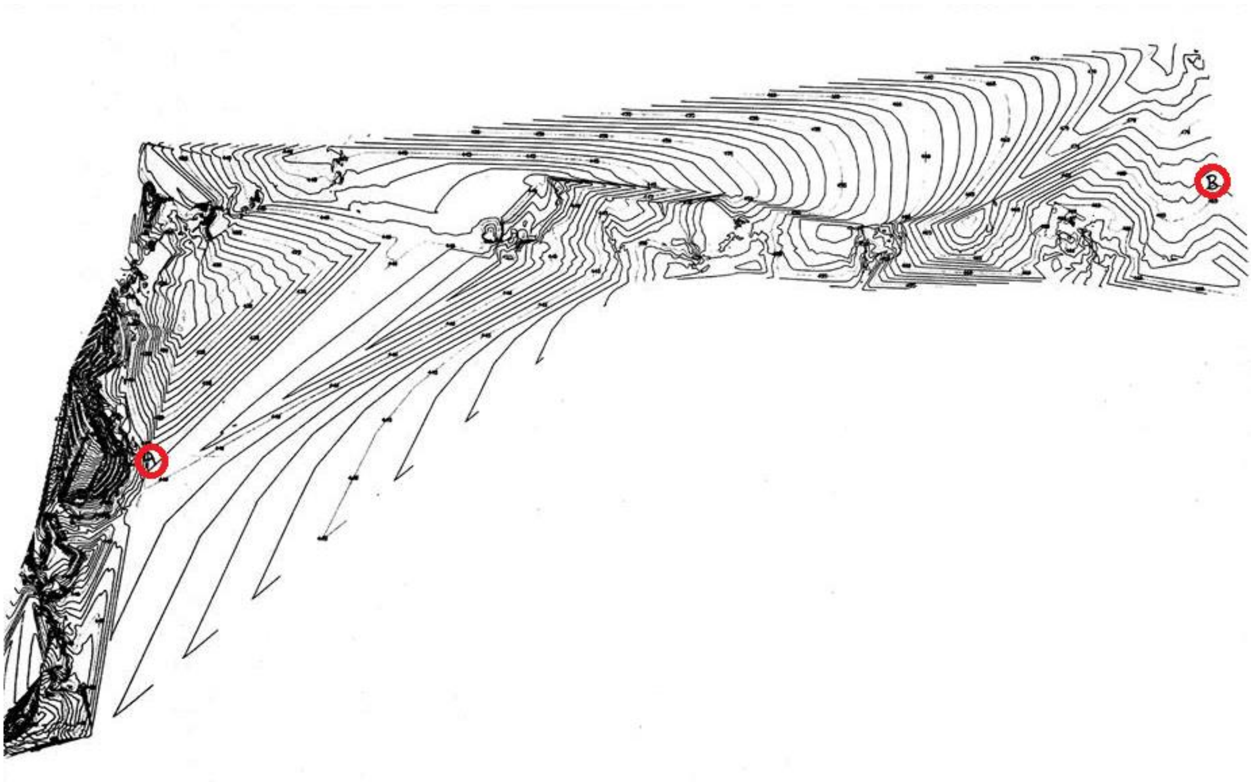
1. Develop two significantly different alternative routes, with an operating speed of 40 KMPH, between points A and B. Select the better alternative and give the reasoning behind this decision.

2. Address the route location, layout of horizontal and vertical alignments, and cross-section components of a rural 2-lane road, under the given constraints of geometric design.

3. Develop your alternatives in a way not to violate a 12% max grade constraint and assume a maximum 10% superelevation rate for critical curves, recognizing the critical curves (i.e. the sharpest curves allowed) that are to be avoided as much as possible.

4. Show the typical cross-sections used in tangent sections and at horizontal curve sections. Calculate the total approximate earthwork and total excavation balance, filling minus cut volumes, for your entire alignment.

II) Map of the site



Routes are decided between point A and B which are in circled. Distance between the point A and B are given 1km.

III) BACKGROUND

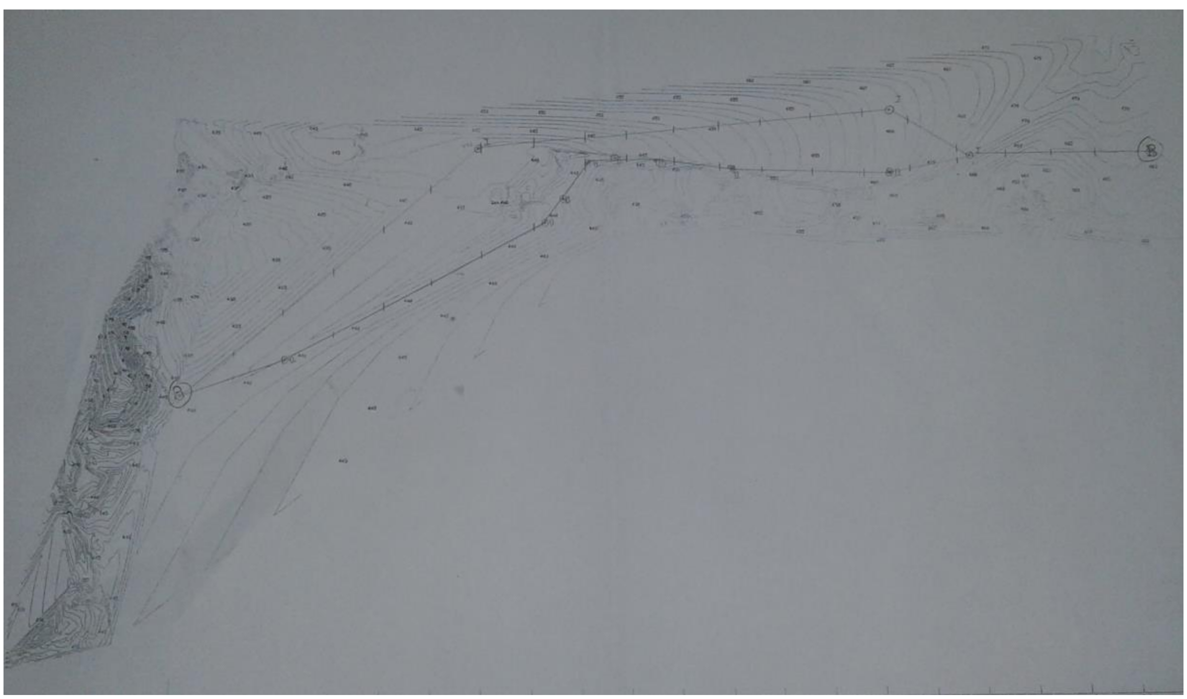
Design criteria are the targets to be accomplished in a design. They are used to differentiate among unacceptable designs, acceptable but poor designs, and good designs. Criteria include *requirements*, which are constraints that must be met; *standards*, which are the constraints that should be met; and other criteria by which the quality of the design is measured.

Non-mandated criteria are called *measures of performance*. These include minimizing total cost, often considering the balance between initial cost and lifetime costs. Other important MOPs which commonly apply to road design include minimizing the land impacted; minimizing excavation; minimizing right-of-way needed; minimizing intrusion into natural water courses; minimizing destruction of trees, other vegetation, animal habitat, historical and cultural sites, established neighbourhoods, and established businesses; avoiding air pollution impacts on nearby sites; and enhancing aesthetic values.

<u>Some guidelines for laying out trial road alignments:</u>

- Each trial horizontal alignment should be laid out with the 12% maximum grade standard.
- Avoid attacking hills and angles that create long ground slopes exceeding the 12% maximum gradient or 10% maximum banking (superelevation).
- Bridges and tunnels are a possibility but due to their enormous costs, they should be avoided as much as possible.
- Horizontal Curves and Vertical Curves should not be too sharp.
- There should be no sudden change in horizontal and vertical slope, if required it must be feasible.

IV) Proposed roads (Road I and Road II) on the map



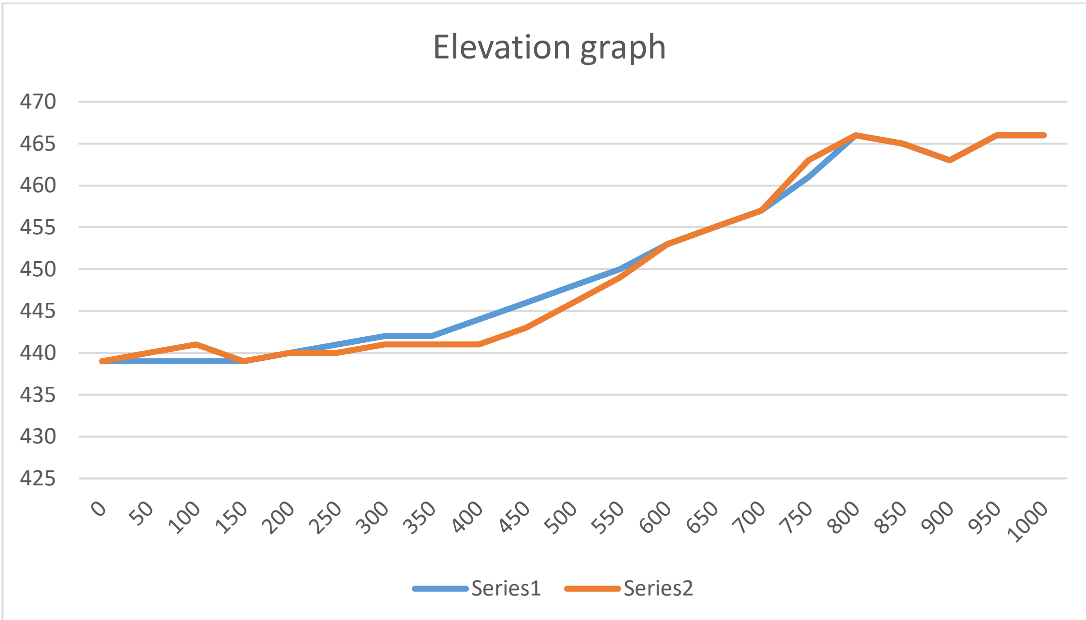
V) METHODOLOGY

Following steps were taken for the purpose of this assignment:

1. The distance between x-coordinates of points A and B is 1 km. This 1 km expanse was divided into 20 divisions of 50 m each.
2. Plot two different roads on the map.
3. Further, a grid was formed in the horizontal plane to identify the x-coordinate of every point in the expanse.
4. By intersecting such grid lines with the given contour line map, we can get the altitude (elevation) of 20 points on the road, each of which are 50 m apart in their x-coordinates.
5. Hence we formulated a table with elevations of 20 points for each of the alternative roads.

X-Coordinate (m)	Elevation(m)	
	I	II
0	439	439
50	439	440
100	439	441
150	439	439
200	440	440
250	441	440
300	442	441
350	442	441
400	444	441
450	446	443
500	448	446
550	450	449
600	453	453
650	455	455
700	458	457
750	461	463
800	466	466
850	465	465
900	463	463
950	466	466
1000	466	466

6. We then developed a chart with the above values plotted to get the Elevation Profile of the two alternatives.



7. The vertical curves were then smoothened out and the total excavation and filling volumes were calculated. With this we computed the total earthwork carried out and the total excavation balance.
8. The horizontal profile was then analysed to see which road alternative has the minimum length, thereby the minimum area impacted.
9. The qualitative and quantitative comparison of the two alternatives were done and the better option was chosen for the purpose of road alignment.

VI) COMPARISON OF ALTERNATIVES

Qualitative Comparison

1. The proposed vertical ground profile of Alternative I is smoother as compared to the Alternative II. Although, there is less variation in existing vertical ground profile of Alternative II.
2. The proposed vertical ground profile of Alternative II is steeper on some spot than that of Alternative I, but this slope is well within the maximum gradient constraint.

3. The earthwork involved in the Alternative I is substantially lesser compared to Alternative II. This is because of the smoothening that would be required in the case of Alternative II towards the end.

Quantitative Comparison

1. The route lengths of the proposed alternatives are:
   Alternative I – 1124 m
   Alternative II – 1108 m

2. The total earthwork (excavation + filling) to be carried out *:

   a. Excavation in Alternative I – 4293.75 m^3
   b. Filling done in Alternative I – 443.5 m^3
   c. Excavation in Alternative II – 3750.5 m^3
   d. Filling done in Alternative II – 2735.5 m^3 (negligible)

   Alternative I – 4737.25m^3

   Alternative II – 6486.00 m^3

   The ratio of net earthwork is = 0.730 (≈ 8:11)

3. The total excavation balance (net excavation) is *:
   Alternative I – (3850.25) m^3 Alternative II – 1015 m^3
   The ratio of net excavation is = 3.79 (≈ 19:5)

4. The number of horizontal curves in the proposed alternatives are:
   Alternative I – 3 Alternative II – 2
5. The number of vertical curves in the proposed alternatives are:
   Alternative I – 3 Alternative II – 6

**Assumptions* –*

1. The width of the proposed 2-lane road is taken as 7.5 m.

2. The distance between each point separated by 50 m in its x-coordinate is 50 m (road length assumed to be 1000 m, not the ones calculated in point 1).
3. We only take into account the x and z coordinates and not the y-coordinates.
4. fs is taken as 0.15.

Justification for the assumptions taken –

The actual excavation and filling could be marginally to substantially higher than the computed ones, but since the Alternative II is the one that curves more in y-axis (larger length, see point 1), it would be Alternative II where there would be a larger increase in both excavation and filling.

Since we have chosen Alternative I for the purpose of road alignment, the removal of the above assumption would only strengthen our decision as the ratios calculated in points 2 and 3 would be more drastic and more in favour for Alternative I.

Identifying Critical Curves

For the purposes of calculating minimum feasible radius of curvature, we use the superelevation formula:

$$R_v = \frac{V^2}{g(f_s + e)}$$

Using the above formula, taking f_s as 0.15 (friction taken for constant velocity – IRC), v as 40 km/h (given operating speed) and limiting e to 0.10 (given constraint), we get $R_{min} \approx 50.38$ m. This means that any horizontal curve with a lesser radius of curvature than this would be unsafe to travel upon.

There are a total of 3 horizontal curve in Alternative I and 2 in Alternative II. The radius of curvature of each horizontal curve is listed below:

Alternative I: Turn 1 – R = 74.10 m

Turn 2 – R = 62.98 m

Turn 3 – R = 74.10 m

Alternative II: Turn 1 – R = 83.18 m

Turn 2 – R = 66.30 m

From the above radii, we identify critical curves for each alternative. Hence, Turn 1 of Alternative I and Turn 2 of Alternative II are the critical curve which need to be investigated upon.

$$e_{cal} = V^2/225R$$

Using the above formula for computing the operating superelevation, we get e_{cal} less than 6% for each of the identified critical curves. Since this is considerably less than the 10% superelevation constraint, all the horizontal curves in both the alternatives can be deemed safe to drive on.

The small amount of superelevation required for the horizontal curve will also serve the purposes of a camber.

Reasons for Choosing Alternative I over Alternative II

1. The cost of building a road is a function of the length and width of the road, materials used, and the earthwork done. Since the road length and earthwork values in Alternative I is lesser than that of Alternative II, it is the optimal choice.
2. Net excavation value is higher in case of Alternative 2 as compare of Alternative 1.
3. In the case of Alternative I, we can use the excavated material as excavation volume is much greater than the filling volume. We can sell it or we can use it in road construction.
4. Alternative I have less numbers of vertical curves than Alternative II.

Conclusions drawn from the above reasons:

Any other differences between the both the alternatives do not account for a major decision variable. Since all the mentioned points are in favour of Alternative I, it is the obvious choice for the purposes of road alignment.