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*S*ignificance of *S*uperelevation in *D*esign of *H*orizontal *C*urves of *H*ighways

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Abstract: ***The superelevation of horizontal curves in highways provides centripetal force in from friction such that the vehicle can safely maneuver the curve at reasonable speeds. The curve provides a path between two tangent lengths of roadway. In this research paper, I will explore the significance of horizontal superelevation and then use the Agra-Lucknow expressway to illustrate its calculation in real life situations.***

1. PREAMBLE & ACKNOWLEDGMENT

1.1 In IB physics higher level,I have studied the laws of physics relating to angular displacement, centripetal and centrifugal forces as part of a chapter on 'Uniform Circular Motion'. The examples given on the practical instances of centripetal force in daily life evoked avid interest in me to knowmore about it more and its significant in design of curves of roads and highways. I approached PNC Infratech Limited, a road design and construction company located in Agra and with their permission I selected one of their highway projects namely 'Construction of Section I of Agra-Lucknow Expressway on Engineering-Procurement-Construction mode' to study on preliminary design aspects of one of the horizontal curves in the shape of a 'trumpet' constructed as part of the expressway (hereinafter referred as 'Trumpet'). The drawing showing the alignment plan of the 'Trumpet' provided by PNC Infratech Limited is appended below as **Figure 1**.

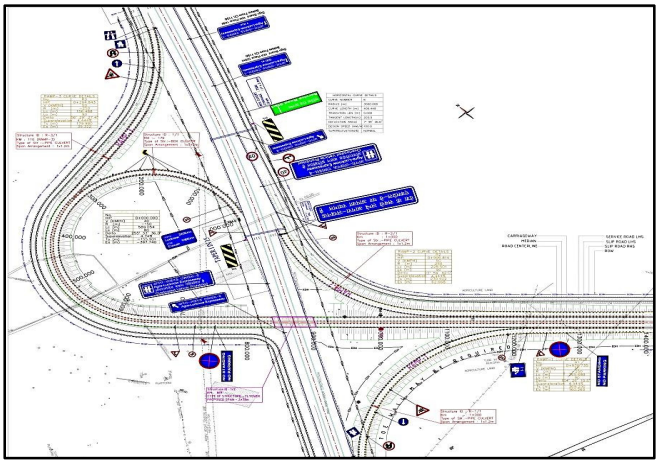

Fig. 1. ***(Source: PNC Infratech Limited)***

1.2 I express my thanks and sincere gratitude to Mr. T. R Rao, Executive Vice President (Infrastructure), PNC Infratech Limited, who has actively coordinated the construction of Agra-Lucknow Expressway project and provided me the information and valuable guidance in shaping this project work.

2. CENTRIPETAL & CENTRIFUGAL FORCES

2.1 **Centripetal Force**: When a particle or a body moves with a uniform speed 'v' on a circular path or radius 'r', then it has centripetal acceleration whose magnitude (v^2/r) remains constant but whose direction continuously changes and remains always towards the center of the circle. According to Newton's law, an acceleration is always produced by a force whose direction in the same as that of the acceleration, hence it is clear that a body performing circular motion is acted upon by a force which is always directed towards the center of the circle. This force is called 'centripetal force'. The name centripetal indicates the direction (towards the center) of this force. In the absence of this force the circular motion is not possible. If 'm' is the mass of the body, then the magnitude of the 'centripetal force' is

$$F = \text{mass} \times \text{acceleration}$$

or

$$F = mv^2/r$$

It is also learnt that centripetal force is not any new force, any of the forces found in the nature (such as frictional force, gravitational force, electrical force, magnetic force, etc.) many act as a centripetal force and we come across in our daily life many instances involving centripetal force.

2.2 **Centrifugal Force:** There are certain situations in which one feels that a body is acted upon by a force. Suppose that a body of mass misplaced on a smooth circular table which is rotating with a uniform angular velocity around a nail passing through the center of the table. Suppose the distance of the body from the nail is'r' and the linear velocity of the table at the body is 'v'. If there is no sufficient friction between the table and the body, then in

order to keep the body at rest on the table it must be tied on the nail by string.A man standing on Earth and looking at the rotating table will see the body rotating around the nail and find on it a 'centripetal force' mv^2/r. This force is provided by the tension in the string and is a real force acting on the body. To another man, however, who is standing on the table, the body appears at rest because its position is not changing with respect to the man. Thus, from the point of view of this man there should be no force acting on the body. But actually, the body is acted upon by an inward force mv^2/r. Hence according to the man standing on the moving table, a force of magnitudemv^2/r is also acting outwards so that the net force on the body is zero. This apparent outward force is called 'certrifugal force'. Although the certrifugal force is an apparent force, but its effect is clearly observed by the man standing on the table. If the string of the body is cut then to the man standing on the table, the body would appear moving radially outwards. According to him the 'centripetal force' being no longer (as the string has been cut) the body is moving outwards under the 'centrifugal force'. If, however the same event is observed by the man standing on the Earth, then according to him as soon as the string is cut, the body moves in the directions of the tangent to the circular path, as required by Newton's First law. This man would not feel any 'centrifugal force'.Infact, when a person stands on a rotating platform then he feels the 'centrifugal force' and its effect. If we stand ona rotating merry go around without holding its strings, we would fall outwards as if have been acted upon by some certain force (centrifugal force). To stand on the merry go round, we must stretch the strings outwards so that by action-reaction law, the string may pull our body inwards and provide the necessary 'centripetal force'. Similarly, if we are sitting in a car which suddenly turns towards right, then we are struck with the left side of the car; this is not because some real force directed towards left has acted upon us. Infact, when the car turned to the right, our body continued to move straight and we struck with the left-handside and felt the 'centrifugalforce' acting on our body.

2.3 Practical Instances of Centripetal & Centrifugal Forces

A vehicle moving on road, requires a centripetal force while taking a turn to counter the 'centrifugal force'. As these vehicles are heavy, the necessary centripetal force may not be provided by friction alone and moreover the wheels of vehicle are likely to suffer considerable wear & tear. In this case the 'centripetal force' is produced by sloping down the road inwards at the turn. By doing so, the vehicle leans inwards while taking turn and the necessary 'centripetal force' is provided. This induced slope is called 'superelevation' in case of design of horizontal curves.

3. DESIGN OF HORIZONAL CURVE ('TRUMPET') OF AGRA-LUCKNOW EXPRESSWAY

3.1 Horizontal Curves are one of the two important transition elements in geometric design for highways (along with vertical curves). A horizontal curve provides a transition between two tangent strips of roadway, allowing a vehicle to negotiate a turn at a gradual rate rather than a sharp cut. The design of the curve is dependent on design speed for the roadway, as well as the other factors including friction. These curves are semicircles as to provide the driver with a constant turning rate with radii determined by the laws of physics surrounding 'centripetal force'.

3.2 Design criteria for horizontal curve and significance of superelevation: When a vehicle makes a turn, two forces are acting upon it. The first is gravity, which pull the vehicle toward the ground. The second is centrifugal force, for which its opposite (acting radially outwards), centripetal acceleration is required to keep the vehicle in a curved path. On a level surface, side friction serves as a counteringforcetothecentrifugal force, but itgenerally provides very little resistance. Thus, a vehicle has to make a very wide circle in order to make a turn on the level.In the highway designs, wide turns are generally avoided due to constraints of space and cost. To deal with this issue, horizontal curves are tilted at a slight angle. This tilt is defined as 'superelevation' (e), which is the amount of rise seen on an angled cross section of a road given a certain run, otherwise known as slope. The presence of 'superelevation' on a curve allows some of the centrifugal force to be countered by the centripetal force, thus allowing the turn to be executed at a faster rate than would be allowed on a flat surface. Generally, superelevation is limited to being less than 7% & coefficient of friction is 0.15.The allowable superelevation e for a horizontal curve can be determined by knowing the design velocity V, the coefficient of friction, and the given radius.

$$(e + f) = (V^2 / 127R)$$

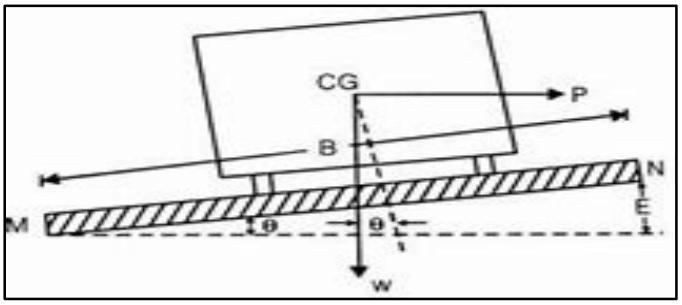

Fig. 2. Superelevated Pavement Section (Source PNC Infratech Limited)

3.3 The salient features of design of the 'Trumpet' :

Assumptions, design parameters considered in the design of 'superelevation' (e) for the 'Trumpet' (loop and curve portions) of expressway are reproduced as under :

Loop :

Design Speed: 40kmph Radius (r) : 150 m

$e+f= v^2/127r$

Consider friction is zero and v is 75% of design speed then

$e= ((0.75v)^2)/ (127r)$

$e = v2/225r$
$e = 402/(225*150)$
$e = 4.74\%$ (Superelevation)

Horizontal curve of Ramp:

Design speed: 50kmph
Radius (r) : 250m
$e = v^2/225r$
$e = 502/(225*250)$
$e = 4.44\%$ (Superelevation)
(Source PNC Infratech Limited)

3.4 The **Figure 3** below shows the Google image of the 'trumpet' after completion of construction :

Fig. 3. Google Image of Trumpet at Agra end of Agra-Lucknow Expressway

4. KEY TAKEAWAYS

4.1 It is comprehended that laws of physics essentially define the design parameters and determine the design of highway geometry including horizontal curves. Design and provision of 'superelevation' (e) on at horizontal curves of highways is critically significant and important for the safe movement of vehicular traffic.

REFERENCES

[1] IRC: 38-1988 "Code of guideline for Design of Horizontal Curves for Highway and Design Table", Indian Road Congress, New Delhi.

[2] IRC: SP: 99: "Manual of specifications and standards for expressways", Indian Road Congress, New Delhi

[3] "Development of Agra to Firozabad (Village Gurha) (Km.-2.634 to 0.000 to 53.500) Access Controlled Expressway (Green Field) Project in the State of Uttar Pradesh on EPC Mode"

[4] Namboodiri, C. K. "Development of a glossary for the technical terms of the NCERT Physics textbooks at senior secondary level." (2018).

[5] Khanna, S. K., and C. E. G. Justo. Highway engineering. Nem Chand & Bros, 1991

[6] "Construction Company In India, Commercial Construction Company In India, Indian Construction Company". Pncinfratech.Com, 2020, https://www.pncinfratech.com/.