Internal Assessment Test 1 Solution – May 2021

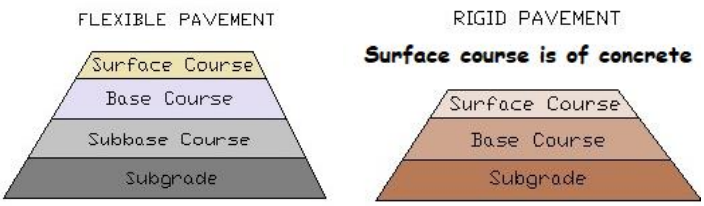
Sub:	PAVEMENT DESIGN	Sub Code:	17CV833/15CV833	Branch:	CIVIL

1	Compare the merits and demerits of flexible pavements over rigid pavements.	[08]

Merits of flexible pavements	Demerits of flexible pavements
• Design life is generally 15 years. To account for a greater design life and if there is a constraint of funds, the pavement can be constructed in stages since the pavement is comprising of layers • Use of Cumulative standard axles for design of pavement accounts for the growth rate and repetetions of traffic • Functional evaluation studies can be easily carried out and it is easy to do functional maintenance by applying a thin bituminous re-surfacing layer. • Structural evaluation can be done at an easier rate by providing an overlay. • It is possible to do milling and recycling of damaged bituminous pavement layers. Hence it has a higher salvage value. • Curing period of bituminous surface course is less and hence the pavement can be opened to traffic in less than 24 hours.	Bituminous layers get deteriorated easily when exposed to stagnant water due to poor drainage and sub-surface water. It is essential to carry out periodic maintenance of the drainage system, shoulders and the pavement surface. It is difficult or expensive to carry out repairs of deteriorated bituminous pavements or patching of pot-holes during the rains or under wet weather conditions. The total thickness of flexible pavement and the quantity of materials required are higher than CC pavements, particularly for the construction of highways passing through weak subgrade soils and carrying heavy traffic loads. For longer service life, life cycle cost is higher than CC pavements when the initial cost, interest on capital and cost of maintenance, resurfacing and periodic strengthening are taken into account. Night visibility is very poor

Scheme:
4 merits and 4 demerits – 8 marks

2	With neat sketches explain the different pavement components and their functions. Highlight its functionality with respect to flexible and rigid pavements.	[08]



Flexible pavement consists of a series of layers with the highest quality materials at or near the surface of pavement. **Rigid pavement** consists of one layer Portland cement concrete slab **and has** relatively high flexural strength.

Both flexible pavement and rigid pavement has a surface course. In case of flexible pavement, for load distribution, surface course will be underlined by binder course as well.

Surface course

Surface course is the layer directly in contact with traffic loads and generally contains superior quality materials. They are usually constructed with dense graded asphalt concrete(AC). The concrete layer of the rigid pavement serves as the surface course and it resists the load by flexural action.

The functions and requirements of this layer are:

- It provides characteristics such as friction, smoothness, drainage, etc. Also it will prevent the entrance of excessive quantities of surface water into the underlying base, sub-base and sub-grade,
- It must be tough to resist the distortion under traffic and provide a smooth and skid- resistant riding surface,
- It must be water proof to protect the entire base and sub-grade from the weakening effect of water.

Binder course

This layer provides the bulk of the asphalt concrete structure.

- It's chief purpose is to distribute load to the base course
- The binder course generally consists of aggregates having less asphalt and doesn't require quality as high as the surface course
- Replacing a part of the surface course by the binder course results in more economical design.

Base course

- The base course is the layer of material immediately beneath the surface of binder course. It provides additional load distribution and contributes to the sub-surface drainage
- It may be composed of crushed stone, crushed slag, and other untreated or stabilized materials

Sub-Base course

The sub-base course is the layer of material beneath the base course and the primary functions are

- To provide structural support, improve drainage, and reduce the intrusion of fines from the sub-grade in the pavement structure
- If the base course is open graded, then the sub-base course with more fines can serve as a filler between sub-grade and the base course
- A sub-base course is not always needed or used. For example, a pavement constructed over a high quality, stiff sub-grade may not need the additional features offered by a sub-base course. In such situations, sub-base course may not be provided.
- For rigid pavement, the sub-base course helps in drainage and reducing md pumping.

Sub-grade

The top soil or sub-grade is a layer of natural soil prepared to receive the stresses from the layers above.

- It is essential that at no time soil sub-grade is overstressed.
- It should be compacted to the desirable density, near the optimum moisture content.

Scheme:
Functions of each layer – 2 marks
For 4 layers – 8 marks

3	Explain frost action. What are its causes and how can it be remedied.	[08]

Frost action: Frost action can be quite detrimental to pavements and refers to two separate but related processes:

- Frost heave. An upward movement of the subgrade resulting from the expansion of accumulated soil moisture as it freezes.
- Thaw weakening. A weakened subgrade condition resulting from soil saturation as ice within the soil melts.

The three elements necessary for ice lenses and thus frost heave are:

- Frost susceptible soil

  This includes
  - Grain size distribution
  - Permeability
  - Capillarity of soil
- Subfreezing temperatures

  This includes
  - Freezing point
  - Duration of freezing temperature
  - Depth to which frost action extends
- Water

  Source of water will be
  - Ground water due to capillary action
  - Soil suction
- Cover

  The rate of heat transfer depends upon
  - Soil density and texture
  - Moisture content
  - Proportion of frozen moisture in the soil

Type and colour of the cover affects the heat transfer from the atmosphere to the soil beneath the cover. For instance, black topped pavement will have higher temperature than a black topped pavement.

Measures adopted to reduce damage due to water and frost action

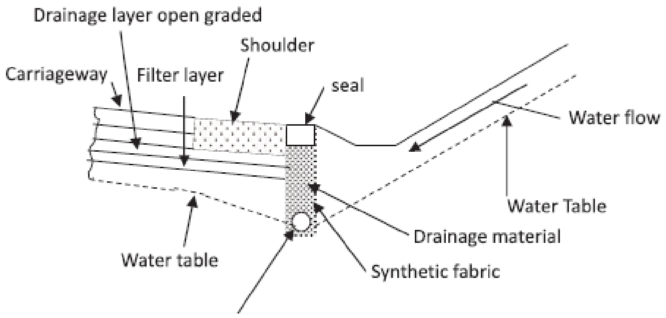
- Install proper surface and sub-surface drainage system
- Construction of base, sub-base and top layer of subgrade. up to the desired depth, by granular and non- frost susceptible material with good drainage characteristics.
- Requirement of filter layer is as follows:

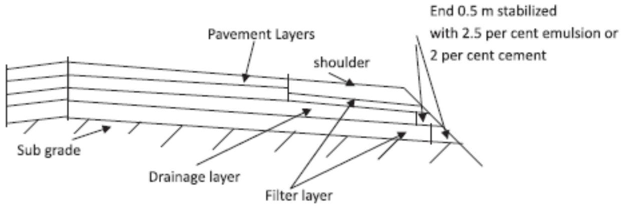
$$\frac{D_{15} of\ filter\ layer}{D_{15}\ of\ subgrade} \geq 5$$

$$\frac{D_{15} of\ filter\ layer}{D_{85}\ of\ subgrade} \leq 5$$

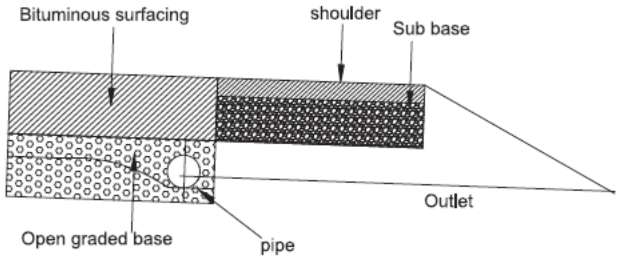
To prevent entry of soil particles into the drainage layer:

$$\frac{D_{50} of\ filter\ layer}{D_{50}\ of\ subgrade} \leq 25$$





Pavement with Filter and Drainage Layers



Longitudinal Pipe at the Edge of the Drainage Layer with Outlet Pipe

- Providing a suitable capillary cut off
- Reduce adverse effects of frost action by soil stabilization so that the soil will be able to withstand the adverse climatic conditions of alternate wet – dry and freeze – thaw cycles.
- Salts like calcium chloride or sodium chloride when mixed with subgrade soil lowers the freezing temperature of the soil – water and hence temporarily decreases the intensity of frost action.

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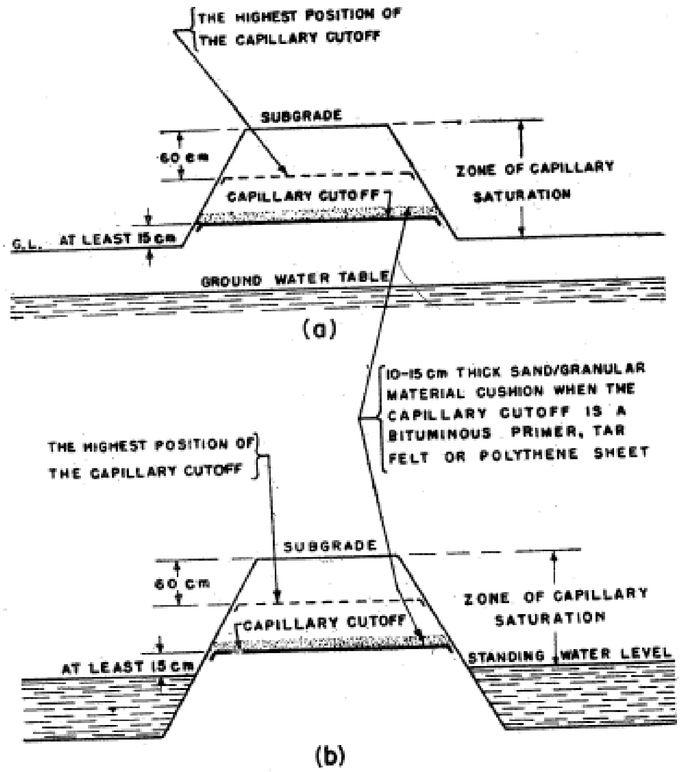

SKETCHES ILLUSTRATING DESIRED POSITION OF THE CAPILLARY CUTOFF FOR PREVENTING THE RISE OF CAPILLARY MOISTURE

Scheme:
Definition – 2
Causes – 3
Remedies - 3
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<td>4</td>
<td>A dual wheel load assembly with 70 kN load on each wheel and contact pressure of 0.7 N/mm^2 is applied on a homogenous mass with modulus of elasticity 12 N/mm^2. If the centre-to-centre distance between the two wheels is 600 mm, determine the deflection value at a depth of 0.5 m at four points, at the centre of dual wheels, and at radial distance of 300, 600 and 900 m from this centre along the line joining centres of the two wheel loads. Use deflection chart.</td>
<td>[08]</td>
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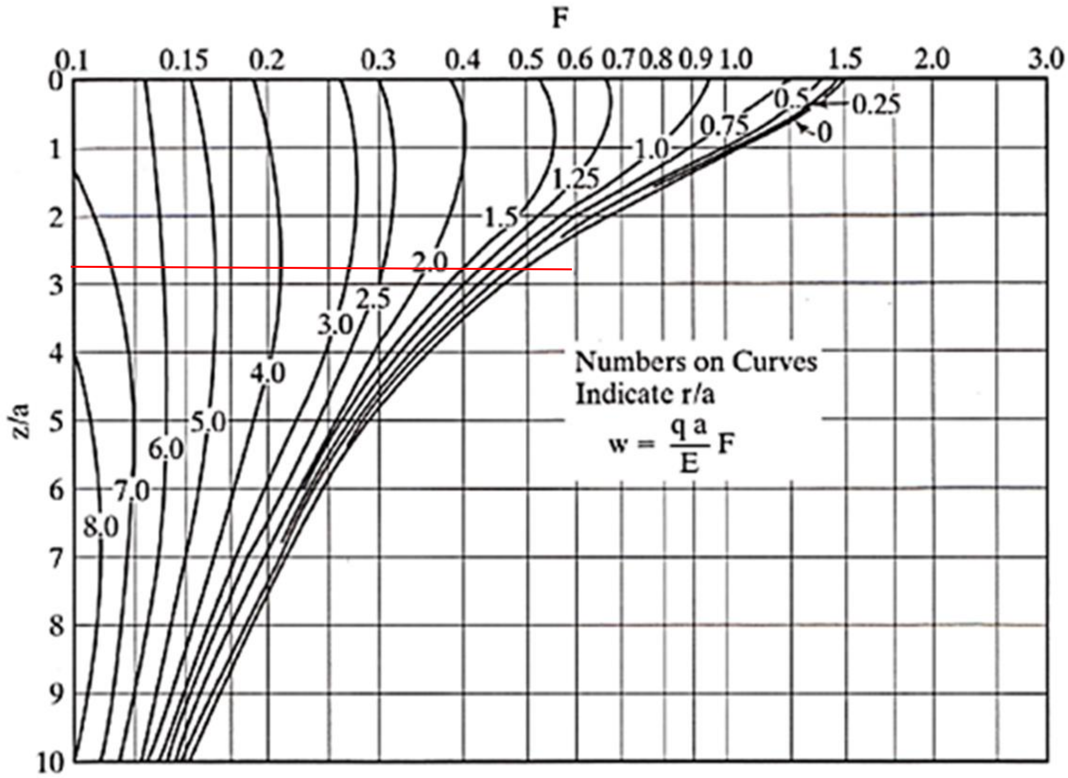
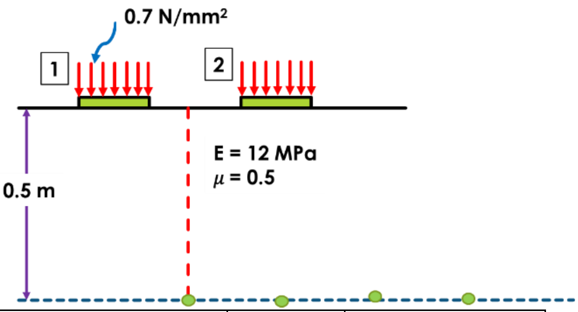


$$\pi a^2 = \frac{P}{p} = \frac{70 \times 10^3}{0.7 \times 10^6}$$

a = 0.178 m

h/a = 0.5/0.178 = 2.81



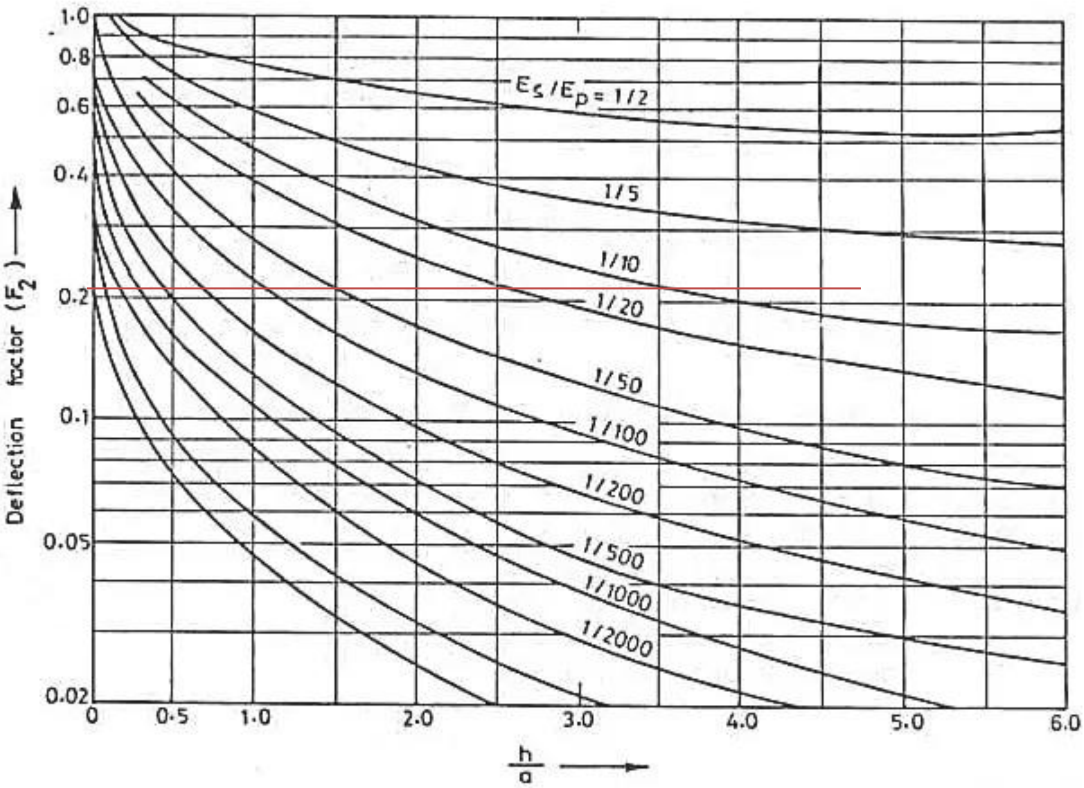
Due to wheel load 1			Due to wheel load 2			F	Deflection in mm
r	**r/a**	**F1**	**r**	**r/a**	**F2**		
0.3	1.69	0.38	0.3	1.69	0.38	0.76	7.89
0.6	3.37	0.26	0	0.00	0.5	0.76	7.89
0.9	5.06	0.17	0.3	1.69	0.38	0.55	5.71
1.2	6.74	0.12	0.6	3.37	0.26	0.38	3.95

Scheme:

Computation of each column – 1 mark

Altogether = 8 marks

5 A plate load conducted with 320 mm diameter plate on subgrade and on a pavement of thickness 400 mm sustained pressure of 0.15 N/mm^2 and 0.5 N/mm^2 respectively at 5 mm deflection. Design the pavement section for 50 kN wheel load and contact pressure of 0.75 N/mm^2 for an allowable deflection of 8 mm using Burmister's approach. If you want to maintain the deflection of 6 mm, what should be the required thickness? [08]



Pavement details:
P = 50 × 10^3 N
p = 0.75 × 10^6 N/m^2

$$\pi a^2 = \frac{P}{p} = \frac{50 \times 10^3}{0.75 \times 10^6}$$

a = 0.146 m
Δ1 = 0.008 m
Δ2 = 0.006 m

Plate load test data:
p_1 = 0.5 × 10^6 N/m^2
p_2 = 0.15 × 10^6 N/m^2
$a = 0.160\ m$
h= 0.4 m
Δ = 0.005 m
h/a = 2.5

Step 1: Determination of E of subgrade

Take F =1; For plate load tests, taking it as a rigid pavement

$$\Delta = \frac{1.18paF}{E_2}$$

$$5 \times 10^{-3} = \frac{1.18 \times 0.15 \times 10^6 \times 0.160 \times 1}{E_2}$$

E_2 =5.664 MN/m^2

Step 2: Determination of E of base course

$$\Delta = \frac{1.18paF}{E_2}$$

$$5 \times 10^{-3} = \frac{1.18 \times 0.5 \times 10^6 \times 0.16 \times F}{5.664 \times 10^6}$$

$$F = 0.3$$

$$For\ F = 0.3,\ Assume\ \frac{h}{a} = 2.5$$

$$\frac{E_s}{E_p} = \frac{1}{8};\ E_p = 8 \times 5.664 = \mathbf{45.31\ MPa}$$

Step 3: Design of pavement (Δ1 = 0.008 m)

$$\Delta = \frac{1.5paF}{E_2}$$

$$0.008 = \frac{1.5 \times 0.75 \times 10^6 \times 0.146 \times F}{5.664 \times 10^6}$$

$$For\ F = 0.28,\ \frac{E_s}{E_p} = \frac{1}{8}$$

$$\frac{h}{a} = 2.7; or\ h = 0.146 \times 2.7 = 0.39\ m$$

Design of pavement (Δ1 = 0.006 m)

$$\Delta = \frac{1.5paF}{E_2}$$

$$0.006 = \frac{1.5 \times 0.75 \times 10^6 \times 0.146 \times F}{5.664 \times 10^6}$$

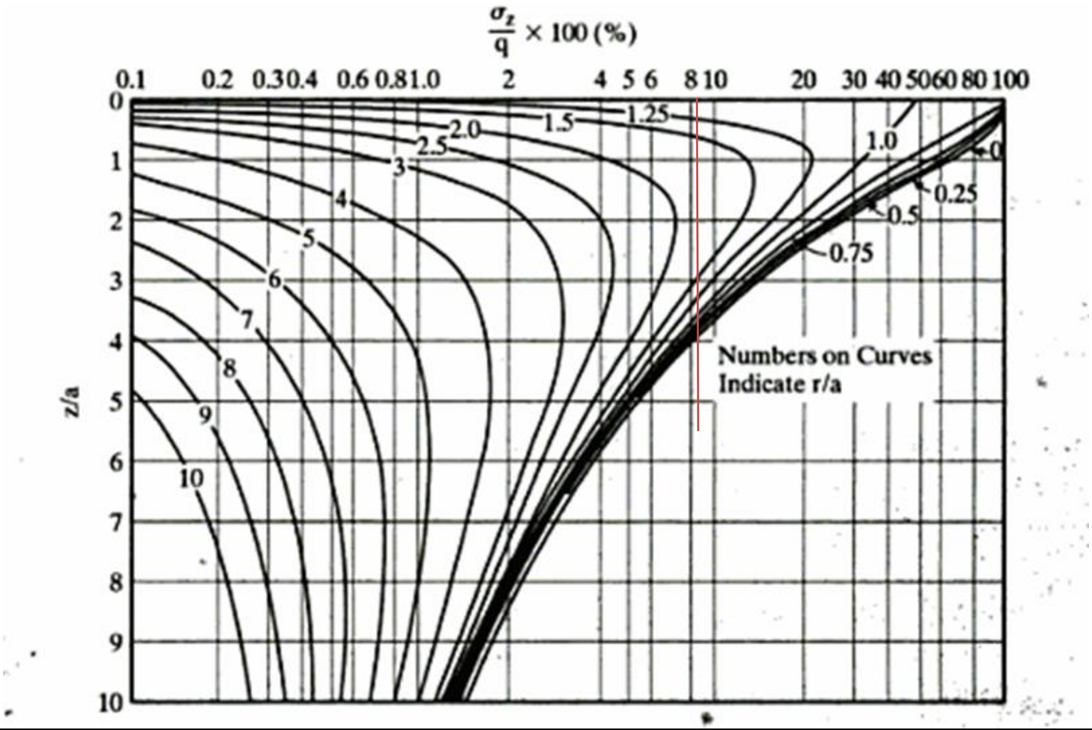
$$For\ F = 0.21,\ \frac{E_s}{E_p} = \frac{1}{8}$$

$$\frac{h}{a} = 4.25; or$$

$$h = 0.146 \times 4.25 = 0.62\ m$$

Each step – 2 mark total 8 marks

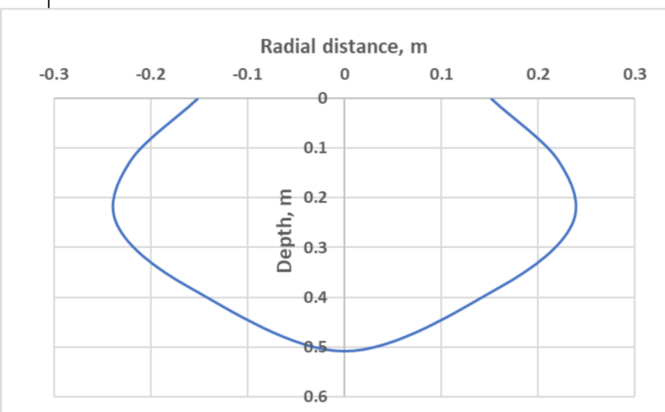
6 A homogenous half space is subjected to single circular load of 254 mm in diameter. The pressure on the circular area is 345 kPa. The elastic half space has elastic modulus of 69 Mpa and Poisson's ratio of 0.5 . For a vertical stress of 28kPa (σ_z) draw vertical stress contour for different depths. Consider the following vertical depths, h/a = 0, 1, 2, 3 and 4. Use Foster and Ahlvin's chart. [10]



a = 0.254×0.5 = 0.127 m

$\sigma_z/q\times100$	h/a	h	r/a	r (m)
8.12	0	0	1.2	0.152
8.12	1	0.127	1.75	0.222
8.12	2	0.254	1.85	0.235
8.12	3	0.381	1.25	0.159
8.12	4	0.508	0	0

r	h
0.152	0
0.222	0.12
0.235	0.25
0.159	0.38
0	0.50
-0.159	0.38
-0.235	0.25
-0.222	0.12
-0.152	0



Scheme: each column 1 mark each = 5 marks
R and h table – 3 mark
Figure – 2 mark

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