HIGHWAY

DESIGN & ENGINEERING

(هندسة و تصميم الطرق)

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((Highway classification))

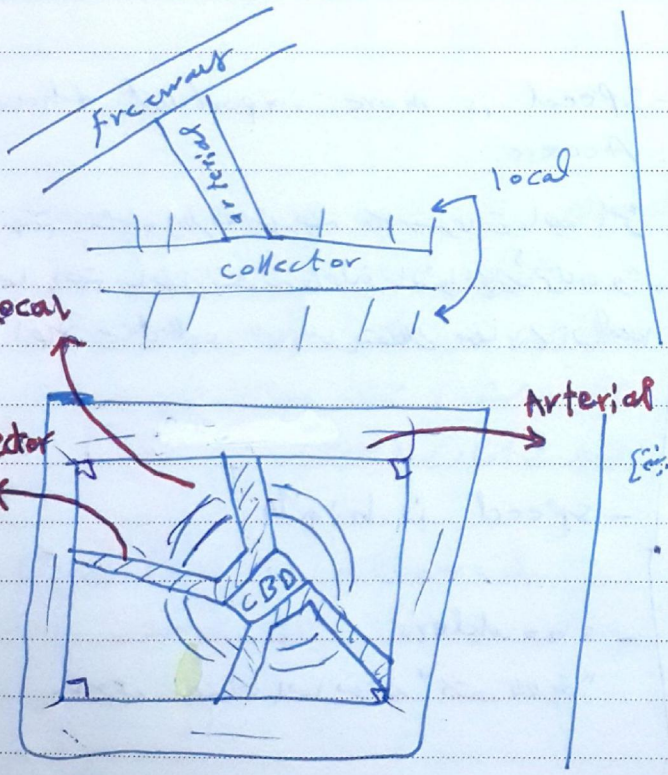
1) According to function (أداء الطريق):-

a- Freeway → [طريق طويلة تصل بين مدن وأسواق عندها نالية]

b- Arterial

c- Collectors (distributers) → [collect the traffic from the local rode to arterial]

d- Local → الشوارع السكنية: تكون السرعات عندها قليلة



* الـ local بجمع الـ collector ثم تذهب إلى الـ freeway لينتقل لمدينة أخرى يعلم بعلم arterial.

* لا يجوز أن يلتقي local & freeway بسبب تفاوت السرعات المسموحة بينهما.

* CBD: Center Business distance [مركز المدينة]

local → collector → Arterial → Freeway

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2) According to Responsibilities:-

a- urban road داخل المدن / بلدية

b- Rural road خارج المدن / أشغال

داخلي urban	خارجي Rural
- Land expensive • بنهتم بهذا الامر لأننا بندفع تعويض لأصحاب الاراضي اللي بدنا بقيم عليها طرق.	Land is cheap
- Access is more important than the speed. • كطرق داخلية المهم انه تكون الطرق توصل لبعضها حتى يستفيد منها المواطن وذلك أهم من ان يتمكن المواطن من القيادة بسرعات عالية.	- Speed is more important than Access. • يهتم بتصميم الطرق الخارجية على سرعات عالية أكثر مما اهتم بأنها تكون واصلة بالشوارع الأخرى، و أهلا في الحالات هي اللي بتنقلك منها لـ ار العمل
- speed is low	- speed is high
- side wokes, curbs • يوجد رصيف على جوانب الطرق.	- shoulders • لا يوجد رصيف إنما يوجد "كتف الطريق"
- drainge is important • يوجد تصريف المياه لغسل الشوارع، حتى ماتدخل على المساكن.	- Drainge is less important • لا داعي لوجود تصريف لعدم وجود مساكن تتأثر بالمياه الساقطة على الطرق لذا فالمياه تصريفها سطحي ذاتي • في حالة وجود اودية حولها نرفع الجسر.

- street Lighting • من المهم وجود إضاءة للطريق	- Less street lighting • ممكن الاستغناء عن الإضاءة ولكن ممكن استبدالها بعواكس تظهر ملامح الطريق
- Lanes are not wide but have more number. • المسارب كثيرة مشان حركة السير تكون منتظمة ولكن المسارب ضيقة (مش عريضة). • كلما كانت السرعة المصمم عليها أعلى بتكون بحاجة إلى عرض أكبر لذلك نهتم بتعريض المسارب والشوارع في الخارج أكثر.	- Lanes are wide but have less number
- Heary vehicles are not allowed • الشاحنات الكبيرة غير مسموح بدخولها للطرق داخل المدن لأنها بتعيق حركة السير بسبب حجمها الكبير والشوارع الضيقة، لذلك فهي مسموحة فقط في الخارج (Rural).	- heavy vehicles are allowed and important
- Cycling is allowed • cyeling: القيادة بالبسكوليت	- No cyeling allowed
* - pedestrain crossing is important • مهم ان نأخذ بعين الاعتبار حركة المشاة	- pedestrain crossing is less important.
- Loading and unloading are allowed • يوجد مسموح عملية التحميل والتفريغ والعكس بالـ Rural	- No Loading and unloading

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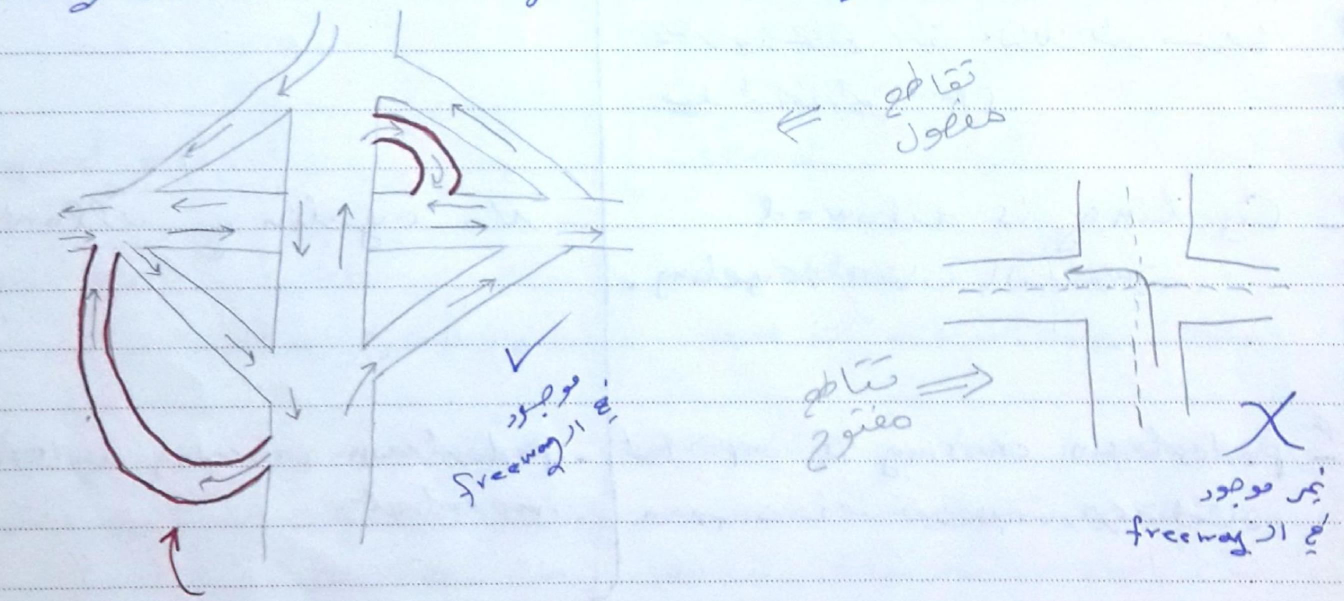
ملاحظة: عرض المسرب الافتراضي (standard width of lanes) = [2.7 - 3.6] متر (m)
= [9 - 12] قدم (ft)

ملاحظة: الحوادث في urban أكثر ولكن خطورتها أقل بعكس الـ Rural ، والسبب في كثرتها في urban هي اكتظاظها حركة السير وكثرة الشوارع والتقاطعات ولكن بسبب تدني السرعة فيها تكون حدتها أقل وعكس تماماً في الـ Rural .

* "free way" ⇒ characteristics: 1) high speed
2) high traffic flow [more lanes]
3) Barries (حواجز) are located on bothsides to prevent entring the road
4) wide lanes (There are heavy vehicles)
5) wide curve
6) Exiting the road is always from the right

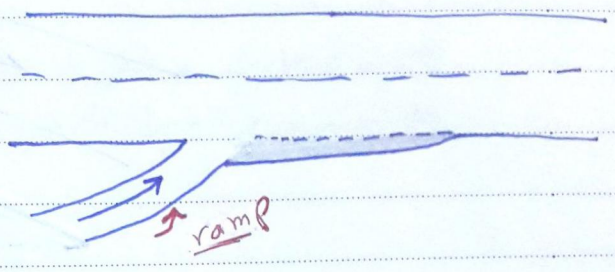


7) Acceleration and declaration lanes are provided.

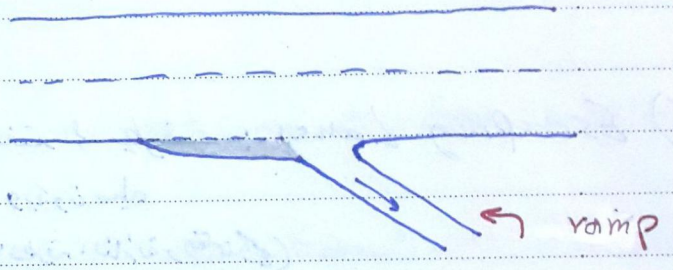
8) freeway are seperated by interchange.

* Types of Lanes (freeway and other highway)

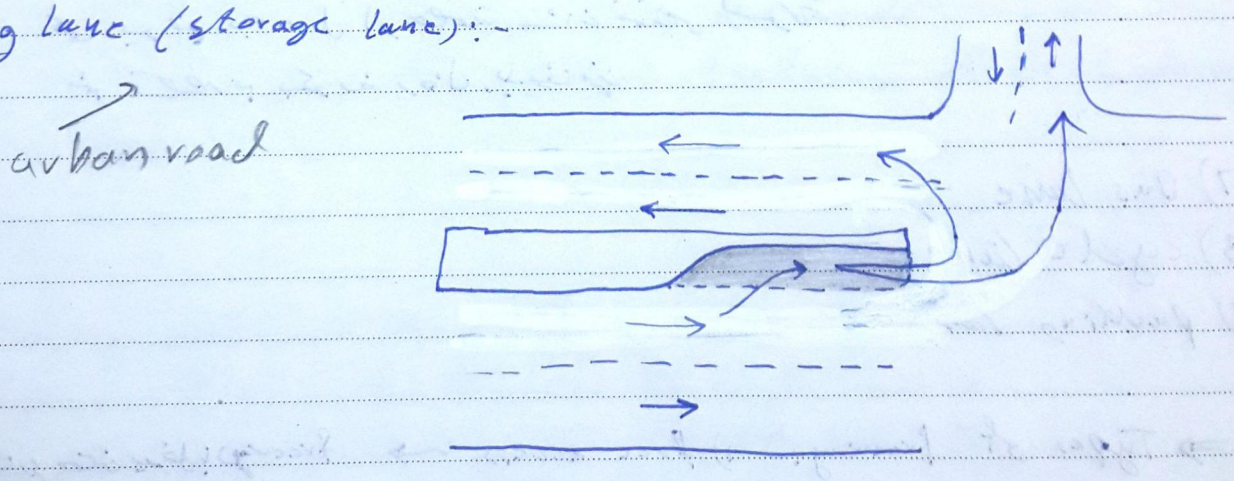
1) Acceleration Lanes :-



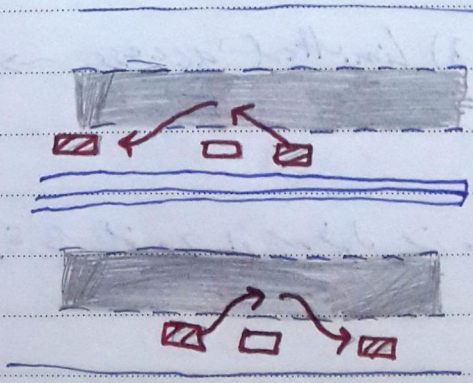
2) Declaration Lane :-



3) Turning lane (storage lane) :-



4) overtaking Lanes :- "مسرب التجاوز"



5) Climbing Lanes: is an additional lane for heavy tucks going on low speed to allow other vehicles to overtaking slow vehicles (for 2 lane highway uphill only)

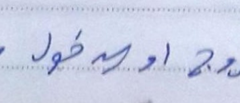
(مسرب للشاحنات عالطلوع
عشان ما تتعطل تلحقها الـ)

6) Escaping Lanes: تستخدم للشاحنات او السيارات لما تفقد السيطرة عليها ، بكون مسرب اضافي للطوارئ وبكون ميله عاكس ميل الشارع الاصلي (طلوع بالطريقة النازلة وعكسها) لما يدفع به رمل او حصمة عشان تخفف السرعة. ثم تصطدم بكومة رمال لإيقافها.

7) Bus lane
8) cycle lane
9) parking lane

⇒ Types of freeway:
1) free access → عند كل شارع ممكن يدخل بالـ freeway بنعمله تقاطع (ramb) او ليرا
2) partially access → عند كل تجمع سكاني خفيف : بس بنعمل تقاطع
3) limitted access → عند كل تجمع سكاني كبير زي مراكز المحافظات (مدن) بنعمل تقاطع

- الهدف من التقاطع: مقدرة ال الخروج او الدخول من وإلى ال freeway .



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{Design speed and sight distance}

- تحديد السرعة التصميمية للشارع معتمدة على نوع الشارع ، وكل ما بدي ازيدها بدي ميل أقل وشوارع أعرض و cut أكثر وبالتالي cost أكثر.

- (sight distance) : هي المسافة اللي لازم تكون موجودة بيني وبين الخطر ، ان وجد يعني لو في حادث او خطر معين ولازم توقف ، فالمسافة من رؤيتي له لعنده ، تسمى sight distance ;

- There are two types of sight distance:
  1) stopping sight distance (SSD):
  It's the distance required to see an object (0.15) m high on the roadway.
  - The design speed that can be maintained over a specified section of the highway when the conditions are so favourable that the design features of the highway governs.

- stopping sight distance depends on:
  1) Reaction time :- لما تشوف الخطر ردة فعلك بتأخذ وقت بسيط ثم تبضغط على الفرامل . وتقدر ب 2.5 ثانية
  2) Breaking distance :- هي المسافة اللي بتقطعها من عند الضغط عالفرامل الى ان تتوقف.

$SSD = d_r + d_b$

$d_r = v * t_r$

$d_b = \frac{v^2}{2g(f \pm G)} = \frac{V^2}{254(f \pm G)}$

(d_b in m; v in m/s; V in km/hr)

+ طلوع
- نزول

/ /

d_r : distance travelled during the reaction time
d_b : " " " " breaking "
V: design speed
t_r: Reaction time AASHTO suggest 2.5 second
g: gravity acc.
G: Average grade
f: friction coefficint between types and pavement

design speed	f
30	0.4
40	0.38
60	0.33
80	0.3
100	0.28
120	0.28

معطى السرعات ، إذا بدك سرعة شاذة بدك تبحث عن (f) اجماصية لها وليس interpolating !!

ex: determine SSD on (−3.5%) grade for a design speed of 110 Km/hr , f = 0.28 , t_r = 2.5 second.

sol ⇒ $SSD = d_r + d_b$

$$= V * t_r + \frac{V^2}{254(f \pm G)}$$

$$= 110 \times 2.5 \times \frac{1000}{3600} + \frac{110^2}{254(0.28-0.035)}$$

$$= 270.8 \text{ m}$$

[illegible]

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• الرقم سابقه 270.8 متر يعني انه السائق إذا كان ماشي على السرعة التصميمية او أقل وشفت خطر بتقدر توقف بعد ما تكون قطعت مسافة ٢٧٠٫٨ م وبالتالي إذا الخطر على بعد اقل من هيك رح يصير حادث ، هذا الكلام إذا مشيت بشكل مستقيم ، طبعاً كل ما كانت السرعة التصميمية أعلى بكون لازم اري طويلة هالمسافة .

ex: a motorist travelling at 105 KM/hr on a freeway in tend to leave the freeway using an exist with maximum speed of 56 Km/hr. at what distance on the freeway should the driver step on his speed to the maximum allowable on the ramp just befors the exit. / grade = -3% / f = 0.35

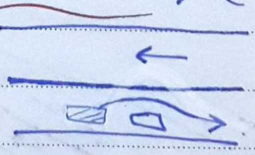
???

soln: $d_b = \frac{V_1^2 - V_2^2}{254\,(f \pm G)} = \frac{105^2 - 56^2}{254\,(0.35 - 0.3)}$

$= 97\ m$

ونهمل dr لانه لما نبطئ الشاخصة نحطها في مكان ممكن رؤيته عن بعد .

2) passing sight distance (Two lane highway) (PSD)



لما بدك تتجاوز ، بكون في عليك خطر إذا طلعلك سيارة مقابلة إلك لذلك نحكم المسافة اللازمة للتجاوز والي ممكن عنه التجاوز إنك تكشف الشارع قدامك هاي هي ال PSD

{ It's the distance required to see an oncoming vehicles of a certain siz minimum (only 2-lane highway)

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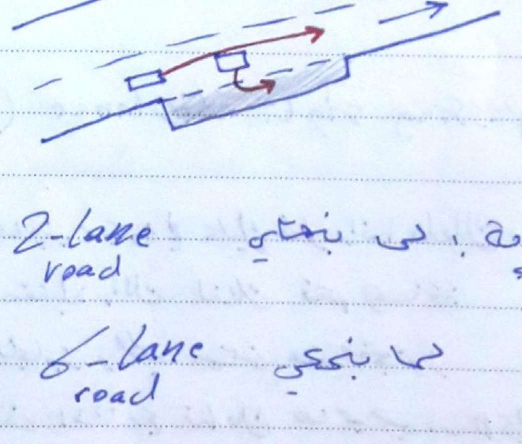
معلومة: اذا الجزيرة الفاصلة بين المسربين الشارع كانت متقطعة بكون مسموح التجاوز
و اذا لا معناته غير مسموح.

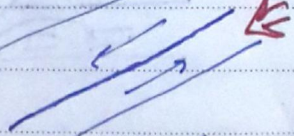
design speed	passing sight distance
30	217
40	285
60	407
80	541
100	670
120	792

- passing zone: It's provided when parking sight dist in not provided through out the length of the highway
  - these zones are for over this operation
  - length of passing zone = 3 - 5 times of PSD

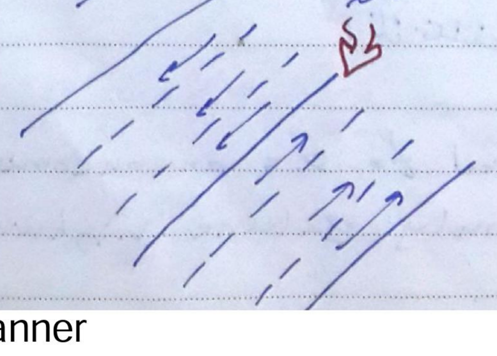
مسرب بضاف مشان السيارة الي متامل تدخل فيه ثم انت تطلع منه
و بستخدم في المناطق الوعرة.



معلومة: لما بنحكي 2-lane road معناته



لما بنحكي 6-lane road معناته

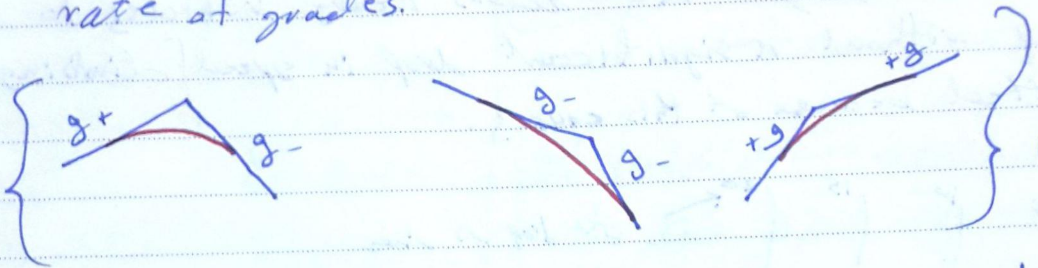


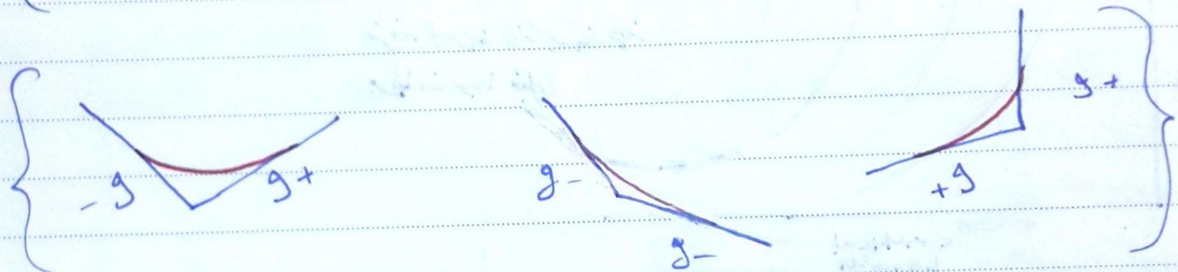
Geometric design

1. vertical Curve (aligment):-

it's conecting profile grade tangent, they can be seen by drawing the highway profile.

- vertical Curves are provided to avoid abrupt changes in the rate of grades.





للتذكير: $\frac{v}{h} = \tan\theta$ = slope = gradient = g

مثال ⇐ $g = 5\% = \frac{5}{100}$

$= \frac{1}{20} = 1 : 20$ (v : h)

→ طلوع متر كل ٢٠م

- The maximum grades recommended for various classes of roadway by AASHTO :-
  - 3% Level terrain
  - 4% Hilly Areas
  - 7% Mountain Areas

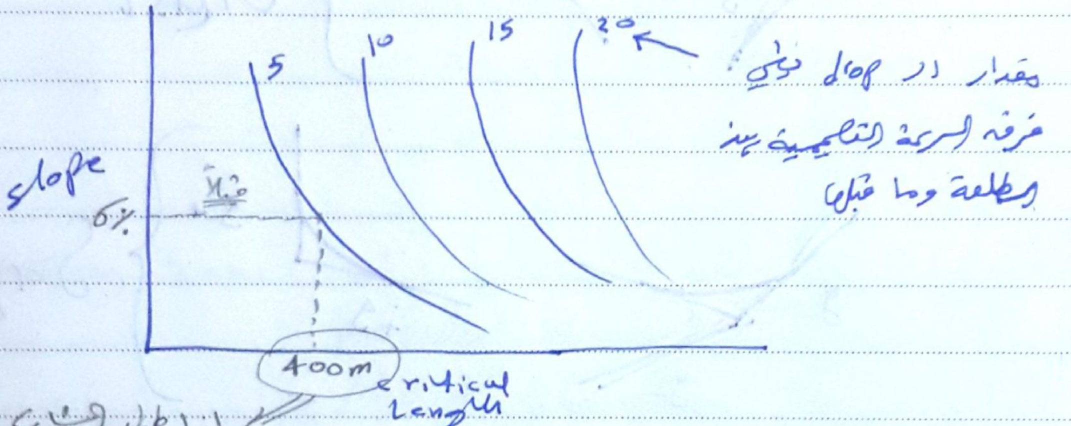
- max. grades depend on :- 1) Topography
  2) design speed

- In urban areas, the slope can reach up to 25% (Accessibility is more important)
- for drainge there must be a minimum slope of 0.5%.

- Critical Length

each grade has a critical length

→ it's maximum length that allows heavy vehicles to climb up without a significant drop in speed [climbing lane putted because of this cause].



إذا طول الشارع
اللي فيه طلوع
أكبر أو يساوي
٤٠٠م معناته
لازم نحط
climbing lane
ومش [illegible]

وللعلم: عمل مسرب إضافي (climbing lane) أرخص من أنني أعمل قص للمنطقة
مشان أخفض الميول.

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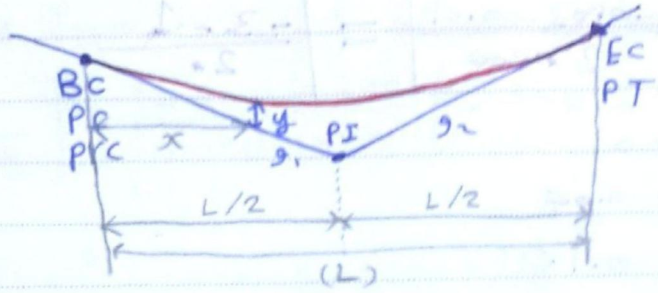
* vertical curve calculations:-

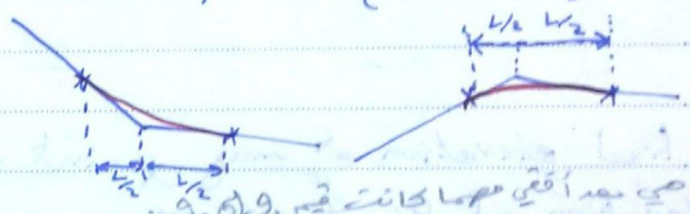


BC: Beginning of curve
PC: Point of curve
PVC: " " vertical curve.
PI: " " Intersection
EC: end of curve
PT: point at tangent
L: Length of curve

- بحيث انه لما يكون في اختلاف بالسلوب بين منطقتين بنعمل (vertical curve) بحيث يكون (PI) في وسط الامتداد الأفقي لل curve.

- مركز التقوس (اخفض نقطة في ال sag curve او أعلى نقطة في crest curve) تكون على سوا ال PI, اذا $g_2 = g_1$ فقط.

- اذا $\{g_1 \neq g_2\}$ تكون القيم هكذا



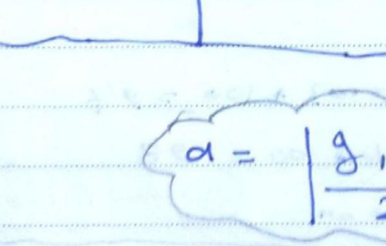
اي أن L هي بعد أفقي مهما كانت قيم g_1 و g_2.

$$y = a x^2 \qquad a = \left|\frac{g_1 - g_2}{2L}\right| \qquad x_m = \left|\frac{g_1 L}{g_2 - g_1}\right|$$

elevation at curve = elevation at tangent + y

EX: (-3%) grade is connected to (1%) by means of (200m) vertical curve, if the elevation at the begining of the curve is (100m), find the elevations of the curve at (20m) interval.

solution:



$$a = \left|\frac{g_1 - g_2}{2L}\right| = \left|\frac{-0.03 - 0.01}{2 * 200}\right| = 0.0001$$

$y_0 = 0.0001 * (0)^2 = 0$

$y_{20} = 0.0001 * (20)^2 = 0.04$

$y_{40} = 0.0001 * (40)^2 = 0.16$

$y_{60} = 0.0001 * (60)^2 = 0.36$

$y_{80} = 0.0001 * (80)^2 = 0.64$

$y_{100} = 0.0001 * (100)^2 = 1$

→ $y_{120} = 0.001 * (200 - 120)^2 = 0.001 * (80)^2 = 0.64$

$y_{140} = 0.001 * (200 - 140)^2 = 0.001 * (60)^2 = 0.36$

⋮

(mirror)

- to find elevation of any point at tangent :-

elevation of BC ± g * X

for example: elv @ PI = 100 − 0.03 * 100 = 97

elv @ PVT = 97 + 0.01 * 100 = 98

⋮ and so on.

station	grade	Tangent elev.	offset(y)	profile elev.
0+00		100	0	100
0+20		99.4	0.04	99.44
0+40		98.8	0.16	98.96
0+60		98.2	0.36	98.56
0+80		97.6	0.64	98.29
1+00		97.0	1	98
1+20		97.2	0.64	97.84
1+40		97.4	0.36	97.76
1+60		97.6	0.16	97.76
1+80		97.8	0.04	97.84
2+00		98	0	98

X_m = distance from BC to lowest point at sag curve (or higest of crest)

$$= \left| \frac{g_1 L}{g_2 - g_1} \right| = \left| \frac{-0.03 * 200}{(0.01)-(-0.03)} \right| = 150 \text{ m}$$

$$y_{150} = 0.0001 * (50)^2 = 0.0001 * \underbrace{(200-150)^2}_{\text{لأنها بعد PI}} = 0.25$$

tangent elev. = 97 + 0.01 * 50 = 97.5

profile elev. = 97.5 + 0.25 = 97.75 m

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* L_{min} for vertical curve:- (SSD)

crest

$$L_{min} = \frac{G S^2}{200 (\sqrt{h_1} + \sqrt{h_2})^2} \quad \text{or} \quad L_{min} = \frac{G S^2}{404} \quad [S \leq L]$$

$$L_{min} = 2S - \frac{200 (\sqrt{h_1} + \sqrt{h_2})^2}{G} \quad \text{or} \quad L_{min} = 2S - \frac{404}{G} \quad [S \geq L]$$

Sag

$$L_{min} = \frac{G S^2}{200 [0.6 + S \tan(1)]} \quad \text{or} \quad L_{min} = \frac{G S^2}{120 + 3.5 S} \quad [S \leq L]$$

$$L_{min} = 2S - \frac{200 [0.6 + S \tan(1)]}{G} \quad \text{or} \quad L_{min} = 2S - \frac{120 + 3.5S}{G}$$

→ $L_{min} = L$ = Minimum Length of the V. curve.

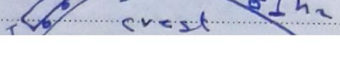
S = Stopping sight distance (SSD)

h_1 = Height of eye above road surface = 1.07 m

h_2 = " " object " " " = 0.15 m

G = ΔSlope = grade algebraic difference

[illegible]



قيمة G اللي بنعوضها بال SSD هي worst case يعني اللي بتعطي أعلى قيمة للـ SSD وبالتالي بنعوض g_1 , $\pm g_2$ $\pm$ وبنشوف الأكبر.

- Longer length of curve provides more SSD but is more costing to construct
- in calculating SSD, we use the worst case (i.e. the steepest slope).

-L7-

ex: Highway is being designed to AASHTO standard with 120 km/hr, design speed and at one section an equal tangent V. curve must be designed to connect grades of (1%) and (-3%), determine the minimum length of the V. curve. Take f = 0.28, tr = 2.5 sec ???

$$SSD = dr + db$$

$$= 120 \times \frac{1000}{3600} \times 2.5 + \frac{\left(120 \times \frac{1000}{3600}\right)^2}{2 \times 9.81 (0.28 - 0.03)}$$

$$\simeq 309 \text{ m}$$

$$L_{min} = 2S - \frac{404}{G} = 2(309) - \frac{404}{1 - -3} = 517 \quad S > L \quad ✗$$

$$L_{min} = \frac{G S^2}{404} = \frac{(1 - -3)(309)^2}{404} = 945 \text{ m} \quad S < L \quad ✓$$

$\therefore L_{min} = 945$

For passing sight distance

- بنهتم بالـ PSD إذا كان عندي ⇐ 1) 2 lane Highway
2) Crest

$$L_{min} = \frac{G S^2}{946} \quad S < L$$

$$L_{min} = 2S - \frac{946}{|G|} \quad S > L$$

- إذا بالـ SSD والـ PSD اعطوك قيمتين مختلفتين، اعتمد الأكبر.

- the main crateria for design a verbical curve :
  1- provide min. SSD + [PSD, if 2 lane. highway & crest]
  2- Adequate drainge (min. slope)
  3 - Comfortable in operation.
  4 - pleasant appearance

- For the crest vertical curve considered only the first crateria (for SSD only), But for Sag V. curve consider all cretaria. (criteria)

- V. curve per AASHTO controls (sag)
  1. for drives comfort use $\{L_{min} = \frac{G V^2}{395}\}$
  2. for general apperance use
     $L_{min} = 30\,G$ if $G > 2$
     $L_{min} = 60$ if $G < 2$

- لا يجوز ان يقل طول الكيرف عن ٦٠ متر
- نختار الأكبر منهم

ex: Find L_{min} of the sag if $g_1 = -3\%$, $g_2 = +3\%$
$V = 65$ km/h, $f = 0.32$ & $t_r = 2.5$ sec
؟ ؟ ؟

1- $SSD = V t_r + \frac{V_b}{254(f \pm G)} = 65 \times \frac{1000}{3600} \times 2.5 + \frac{65^2}{25 \times (0.32 - 0.03)}$

$= 102.5$ m

$L_{min} = 125.78$ for $S < L$ ✗
$L_{min} = 132.31$ for $S > L$ ✓

2- for comfort $\Rightarrow L_{min} = \frac{G V^2}{395} = \frac{6 \times 65^2}{395} = 64.18$

3- for general appearance $\Rightarrow L_{min} = 30\,G = 30 \times 6 = 180$

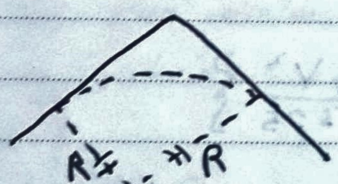
so $L_{min} = 180$ m {الأكبر}

Horizontal Curves

- curves are formed when the road changes direction
- The wider the curve (Bigger radius) the better and safer
- wide curve are in flat areas - more expensive(?).
- sharp curves are in amountain areas
- The higher the design speed the larger the radius is
  {Speed ∝ R}

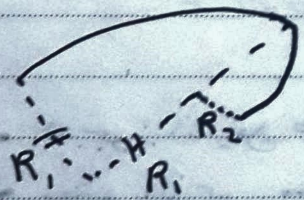
*Types of Horizontal curves:-

① {simple circular curve}:-



- It's a semi-circle between two tangent.

② {compound curve}

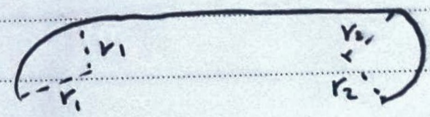


- It's consists of two circles with different radius, this type is adapted when some.
- → obstruction is met with and it's not possible to use one curve with a single radius

- إذا كنت بتسوق السيارة و دخلت على كيرف وكنت مثبت المقود (ستيرنغ) معناته بكون "simple" وإذا حركت المقود بكون الكيرف "compound".
- بستخدم هذا النوع إذا في جزء معين من الكيرف ما قدرت تكمل فيه الكيرف فبتحط شكل كيرف آخر تكمل فيه.

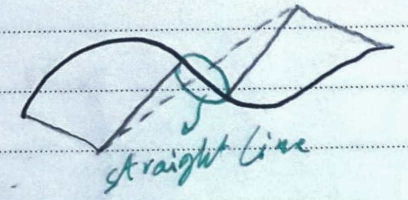
/ /

③ {Broken-Back curve}:-



- كيرفين بينهم خط مستقيم
-

④ Reversed curve

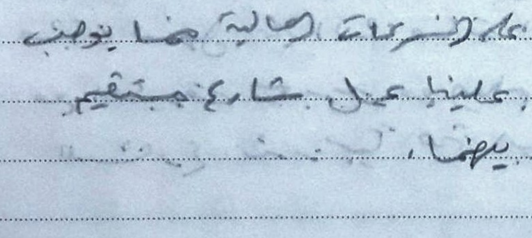


It consists of two curves with different direction, it should be avoided Because:

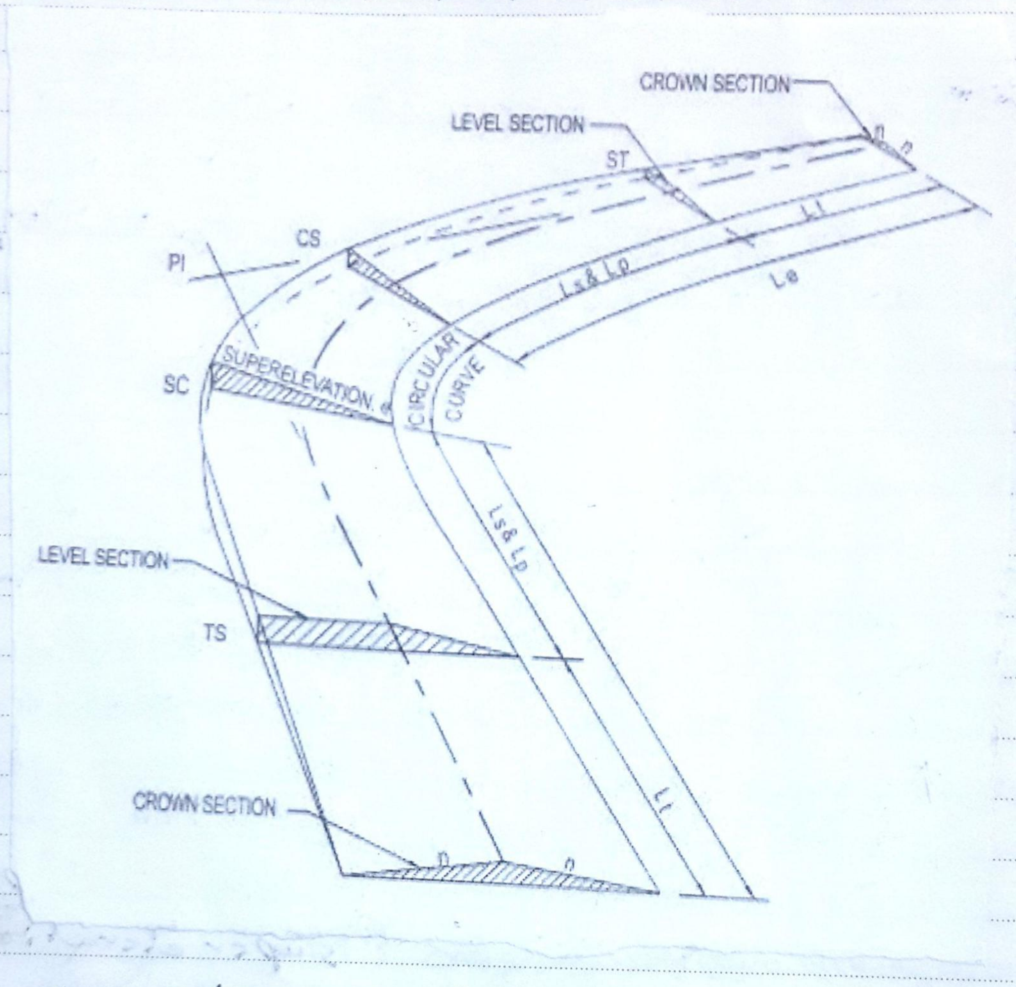
1) it's dangerous
2) difficult to provide super elevation
3) sudden change in direction (uncomfortable)
4) sudden change in supper elevation (it's desirable to insert a straight line between the two curves)

دائماً بالكيرفات بنعمل ميلان في الشارع (بلاحظ من ال cross section) باتجاه ال center وبالتالي في مثل هذا النوع رح نعمل ميلان في الكيرف الاول ثم تعكسه في الكيرف الذي يليه وهذا بيعمل خطورة على السرعات العالية مما يتوجب علينا عمل شارع مستقيم بينهما.

⑤ Transition curve (spiral curve)



- It's curve placed between tangent and circular curve to provide a vehicle path that gradually increases or decreases the radial force as the vehicle enters the curve.



هو طريق بنعمله بنهاية شارع المستقيم قبل الدخول بالطريق الرئيسي
عشان نسهل على السيارات أو القطارات (سكك الحديد) الانحراف تدريجياً
مع الطريق الجديد مع العلم أنه يتم زيادة الميلان العرضي (super elev.)
للشارع تدريجياً حتى الوصول إلى الميلان الخاص بالطريق الرئيسي.

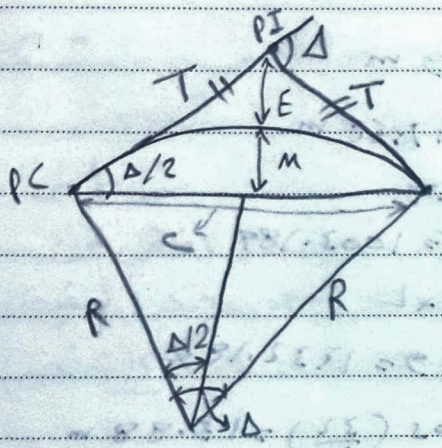
$$L = \frac{0.214\ V^3}{R \cdot c}$$

L: min Transition curve length (ft)

C: Rate of increase of radial acceleration (1.3 – 1.9) m/sec³

R: Radius of the circular curve

V: design speed (mph)



R: radius of circular curve

T: Tangent length

Δ: deflection angle

M: middle ordinate

E: external distance

PC: Point of curve

PT: point of Tangent

PI: " " Intersection

C: chord

$$L = R\Delta_{rad}$$

$$T = R \tan\left(\frac{\Delta}{2}\right)$$

$$C = 2R \sin\left(\frac{\Delta}{2}\right)$$

$$M = R - R\cos\left(\frac{\Delta}{2}\right)$$

$$E = \frac{R}{\cos\left(\frac{\Delta}{2}\right)} - R$$

station of BC = station of PI − T

station of EC = station of BC + L

ex: given a horizontal curve with a radius of 410 m and a deflection angle (Δ) of (32°), and the PI station of (1+120.744), compute the curve data and the station of BC and EC, compute the deflection angle at every (20 m) station???

$L = R\,\Delta_{rad} = 410 \times 32 \times \frac{\pi}{180} = 229\ m$

$T = R \tan\left(\frac{\Delta}{2}\right) = 410 \times \tan\left(\frac{32}{2}\right) = 117.56\ m$

station of BC = station of PI − T

$= 1120.744 - 117.56 = 1003.184$

station of EC = station of BC + L

$= 1003.184 + 229 = 1232.184$

$M = R - R\cos\left(\frac{\Delta}{2}\right) = 410 - 410 \times \cos\left(\frac{32}{2}\right) = 15.88\ m$

$E = \frac{R}{\cos\left(\frac{\Delta}{2}\right)} - R = \frac{410}{\cos\left(\frac{32}{2}\right)} - 410 = 16.523\ m$

$C = 2R \sin\left(\frac{\Delta}{2}\right) = 2 \times 410 \times \sin\left(\frac{32}{2}\right) = 226.023\ m$

Station	x	dx [deg]	Cx
1+003.2	0	0	0
1+023.2	20	1.39	19.89
1+043.2	40	2.79	39.9
⋮	⋮	⋮	⋮
1+232	229	16	226
EC station	L	Δ/2	C

we used in previous table:

$$d_x = \left(\frac{X}{2R}\right)_{\to rad}$$

$$C_x = 2R \sin d_x$$ (→ deg)

i.e:- at $x = 20$

$$d_x = \left(\frac{20}{2\times 410}\right) = \frac{1}{41} \deg \to \frac{1}{41} \times \frac{180}{\pi} = 1.3 \text{ rad}$$

$$C_x = 2R \sin d_x = 19.89 \text{ m}$$

* في الحياة العملية: المسّاح يحدّد مكانه PI ثم من خلال هذه الحسابات تستطيع تحديد مكانه الـ BC والـ EC ثم لتخطيط وتنفيذ المنحنى على الأرض، فاضع الجهاز {total station} على BC ثم بلش كل 20م أستدير بزاوية مقدارها dx وبعد أفقي عن الجهاز بمقدار Cx عندها بكون عندي نقطة على المنحنى وهكذا لبقية النقاط ثم ينفذ بحيث يكون هذا هو الـ C.L للشارع (المنحنى).

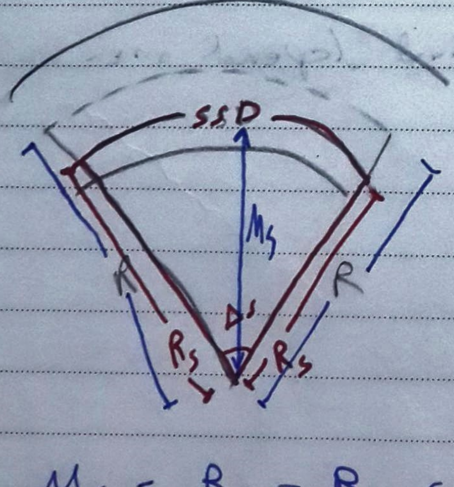
L10

- السائق وهو على الكيرف، لو نظر على جانبه، يجب انه يكشف الطرف الآخر من الـ ، وعلى ذلك هناك اي عوائق لذلك يجب التخلص منها بحيث تكون مسافة المكشوفة من الطريق كافية ومناسبة لرؤية السائق، والحالات التالية توضح ذلك.

$$SSD = R_s \Delta_s \Rightarrow \Delta_s = \left(\frac{SSD}{R}\right)_{\to rad}$$

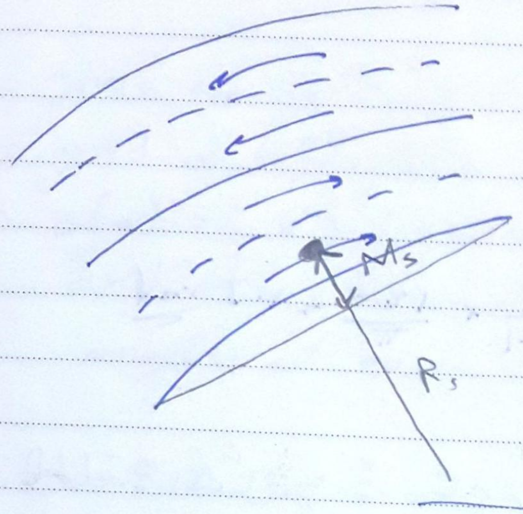
SSD ← تحسب حسب الطريقة السابقة وتعتبر هنا curve

R_s ← نصف R الـ inner lane



$$M_s = R_s - R_s \cos\left(\frac{90 \times SSD}{\pi \times R_s}\right)$$

↑ مقدار البعد العمودي بين منتصف المنحنى بعد الاول واقرب عائق



لو كان عنا 4lane highway بتكون Rs هي من منتصف آخر مسرب
اليي هو فعلياً inner lane

* widening of curves:-

تعريض الطريق عالكيرف مشان السلامة ولأسباب أخرى.

- The traveled way on H.curve in same times widened to make operating condition on the curve similar on these on tangent.
- widening is needed for the following reasons:-
  1) on the driver experiences different in steering around the curve.
  2) By the vehicle accupien a greater width in the rear wheel don't track the front wheel.
  3) For 2-lane highway / extra width = (0.6 – 1.25) m is neccessary.

- the amount of widening needed depend on:-
  1) The design speed طردي
  2) " " vehicle طردي
  3) " curve Radius عكسي
  4) width of road عكسي

Total amount widening:-

$$W = W_{ps} + W_m$$

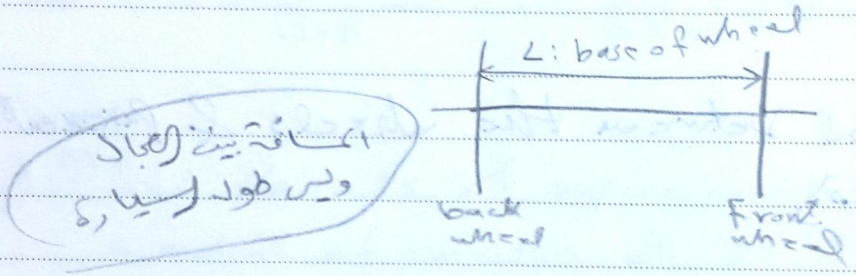
widening at psychological reasont

$$W_{ps} = \frac{V}{9.5\sqrt{R}}$$

V: design speed
R: radius of Horizontal curve

$$W_m = \frac{nL^2}{2R}$$

n: # lanes
R: curve radius
L: wheel base



ex: find the widing H.curve having R_s = 100m, wheel base 6.1 m, formed width 7m, design speed = 70 km/h ?.

$$W_{total} = W_{ps} + W_m$$

$$= \frac{V}{9.5\sqrt{R}} + \frac{nL^2}{2R} = \frac{70}{9.5\sqrt{100}} + \frac{2(6.1)^2}{2\times100}$$

$$= 1.11''$$

superelevation

- The purpose of superelevation of curve is to counteract the centripetal force produces as a vehicle moving around the circular curve.

- vehicle are subjected two main forces:
  1) centrepetal force

$$P = \frac{WV^2}{gR}$$

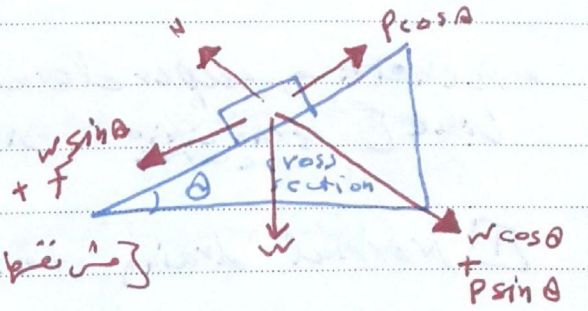
  2) friction developed between the wheels & pavement
     [هو نفسه اللي في الـ SSD]

- At high speed friction force isn't adequate to counter balance the centrepetal force.
- The road must be included toward the center of the curve to provide additional force to counter between the out residual force.
- The inclination is knows as "SUPER ELEVATION".

مهم //
{ يسمح بالـ "super ele" يكون = (١٠-١٢)٪ بالمناطق الغير غنية بالثلوج.
و = (٦-٨)٪ = الغنية بالثلوج.
ولغايات المرور التدريبي للجامعة = (٦-٨)٪ }

{ بعد اعتماد السرعة والـ "superele." يوجد جدول نطلع منه مقدار (R) للـ H.curve. }

$$e + f = \frac{V^2}{127\,R}$$, e = slope = $\tan\theta$



- V: design speed [Km/hr]
  f: coefficient of friction {مش نقط الي بـ SSD}
  R: Radius of H. curve

* If $e = 0$, then the centripetal force is resisted by friction "only" → The speed must be restricted

→ $e + f = \frac{V^2}{127R} \xrightarrow{e=0} f = \frac{V^2}{127R} \rightarrow V = \sqrt{127Rf}$

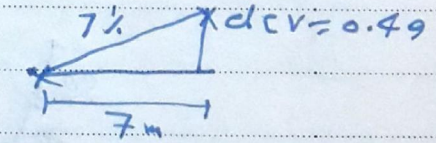
Ex: ① find the rate of superelevation on a H-curve having a radius of curvature of 90 m. The design speed is (50 Km/h), assume $f = 0.15$???

$$e + f = \frac{V^2}{127R} \rightarrow e + 0.15 = \frac{(50)^2}{127 \times 90} \rightarrow e = 0.07$$

→ 7٪

② If the road width is 7m, calculate the rise of banking due to the superelevation ???

$E = e \times B = 0.07 \times 7 = 0.49$



③ If the maximum superelev. is (1 in 15) and $f = 0.15$ calculate the permissible speed on a curve of radius = 180 m ???

$e = 1/15 = 0.067$

$$e + f = \frac{V^2}{127R} \rightarrow 0.067 + 0.15 = \frac{V^2}{127 \times 180}$$

→ $V = 70.43$ Km/h

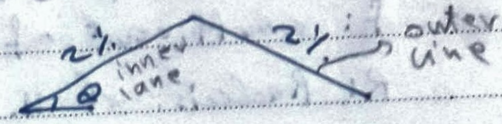
(more safe) 70 km/h

/ /

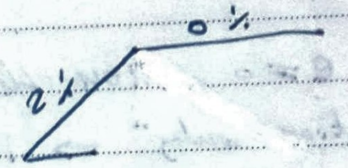
* Acheiving superelevation by rotation around the center line [transition curve تدرج الـ]

{ إذا اعتبرنا ان ميلان الكيرف ٤٪ }

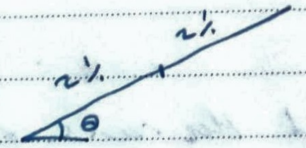
1 Normal draing cross slope



2 outside lane rotated to flat



3 outside lane rotated to normal the cross slope of inner lane

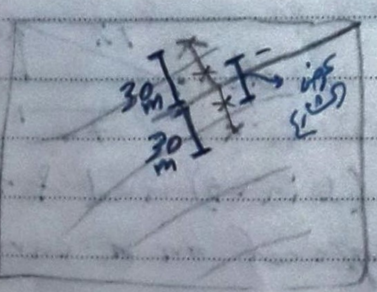


4 Full superelevation

- L12 -

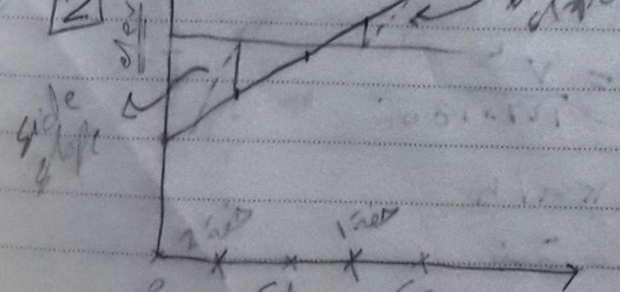
أخذ الـ (cross section) للطريق:-

1



* نحدد الـ "elev" على بعد ٣٠م عن يسار ويمين الـ (C.L).
وكذلك على بُعد يمين ويسار الـ C.L اللذي يوصلني لحواف الطريق

2



* كل ما كان عرض الشارع أكبر خذ مسافة أكبر من ٦٠م وهكذا ويراعى في ذلك مسافات معقولة

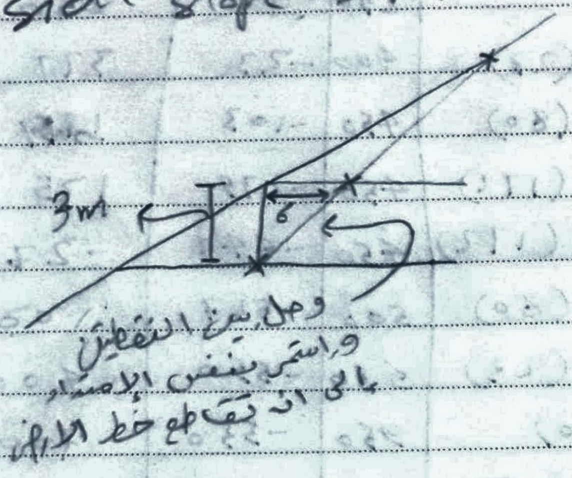
3

Back slope ⇒ cut ⇒ 1 : 2

side slope ⇒ fill ⇒ 1 : 4 (when fill about 3 m)

1 : 6 (" " " 1.8 m)

1 : 3 (لغايات مشروعنا الجامعي)



بما أنه Back slope فإن السلوب 1:2

وبما أن الارتفاع عن الشارع ٣م

إذاً سوف أمشي أفقياً ٦م

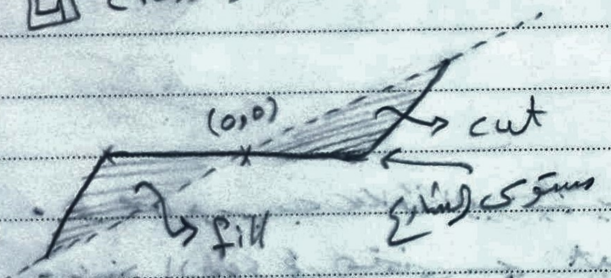
بحدد نقطة وبوصل كما هو في الرسمة

المجاورة إلى أن أقاطع خط الأرض.

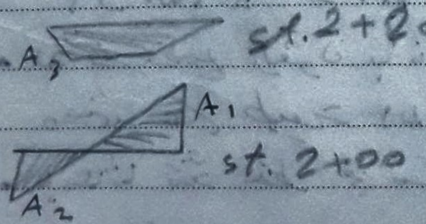
إذا نهاية ال Back slope او ال Side slope كانت متجاورة للأراضي التي تملكها الدولة بالإمكان عدم شراء تلك الأراضي ولكن بالمقابل يجب إقامة جدران إستنادية على حواف الطريق دونه تحمل تلك الميلانات Side و Back.

معلومة

4 cross section shape:



.بحسب مساحة الـ cut والمساحة بال fill لكل section ويوجد كل ٢٠م سكشن. ثم يضرب معدل مساحتين بين السكشنين المتتاليين بالمسافة الواقعة بينهما



$$\text{Volume of cut} = \left(\frac{A_1 + 0}{2}\right) \times 20$$

$$\text{" " fill} = \left(\frac{A_2 + A_3}{2}\right) \times 20$$

Net volume = (V. cut) + (V. fill) × Factor

usually = 1.1 − 1.15

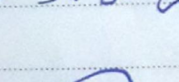
/ /

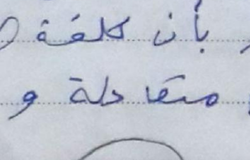
EX:

station	Area cut	Area fill	volume cut	volume fill * (1.15)	commulativ ⊕ cut	commulativ fill ⊖	net
0	15	0	0	0	0	0	0
20	10	0	250	0	250	0	250
40	5	2	150	20(23)	400	-23	377
60	0	5	50	70(80)	450	-103	347
80	0	10	0	150(172)	450	-275	175
100	0	5	0	150(172)	450	-447	3
120	5	2	50	70(80)	500	-527	-27
140	10	0	150	20(23)	650	-550	100
160	20	0	300	0(0)	950	-550	400
180	10	0	300	100(115)	1250	-550	700
200	0	10	100	0	1350	-665	685

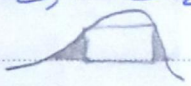
13

* Mass haul diagrame:-

- هو منحنى يرسم به علاقة البيانية بين ال station {X-axis} و ال net vol. {y-axis}
- عند الطلوع في المنحنى ← cut
- " النزول " ← fill
- " الانتقال من cut إلى fill او العكس ← بتكون تلك النقطة ال ground level يساوي ال design level.
- إذا عند نقطة "station" معين كنت بـ صفر ← اي انه عند هذه النقطة ال cut = ال fill
- لا نستطيع القول بأن ال cut ارخص من ال fill او العكس لأنه ذلك معتمد على طبيعة الارض.
- بإمكاننا مد خط في منطقة كهذه  ← حيث يسمى balance line ويدل على انه كمية ال cut تتعادل كمية ال fill ما بين بدايته الى نهايته.
- اذا مددنا خط مثله في مناطق التي يتساوى فيها ال cut مع ال fill تسمى تلك المسافة freehaul distance وتمتاز بأن كلفة العمل بها قليلة نظراً لأن كميات الحفر والردم متعادلة ويستفاد منها لبعضها مباشرة (حفر وطم بعدها).

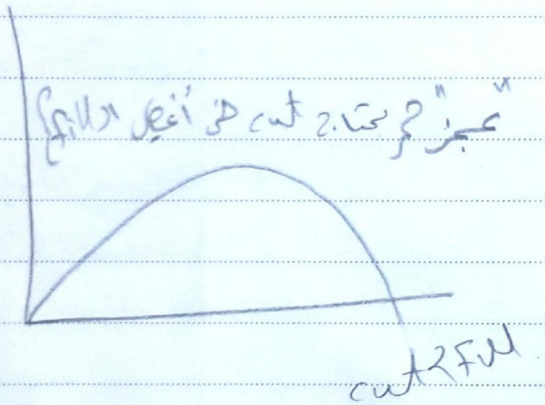


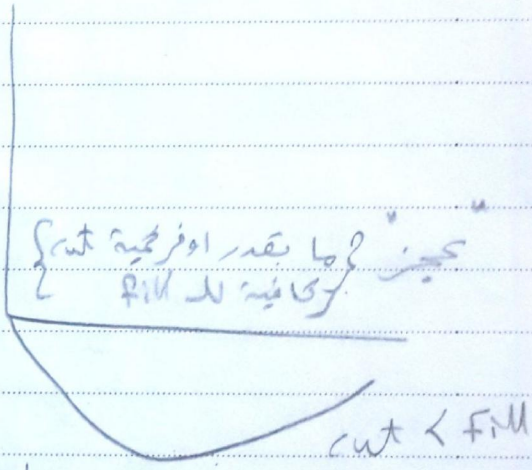
- تسمى المنطقة "الاجزاء" الصغيرة المحيطة بالـ freehaul بالـ borrow/waste حيث يتم ازالتها دون الاستفادة منها بسبب تكاليف نقلها لمسافة بعيدة.

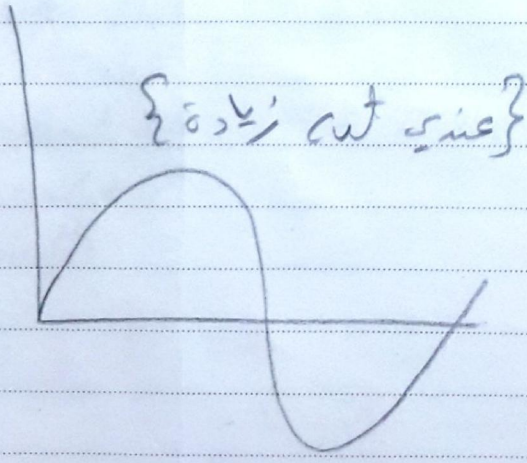


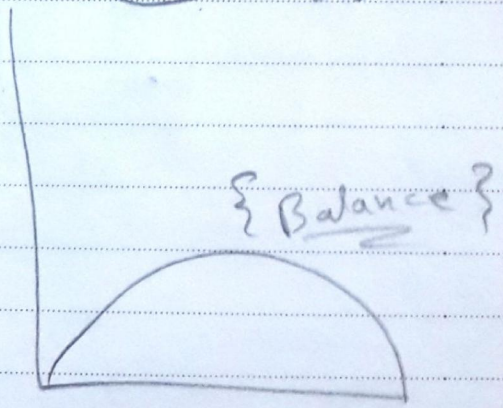
- ولكن من الاجزاء الاتزال إنها تبقى ويمكن الإستفادة منها وتسمى over haul

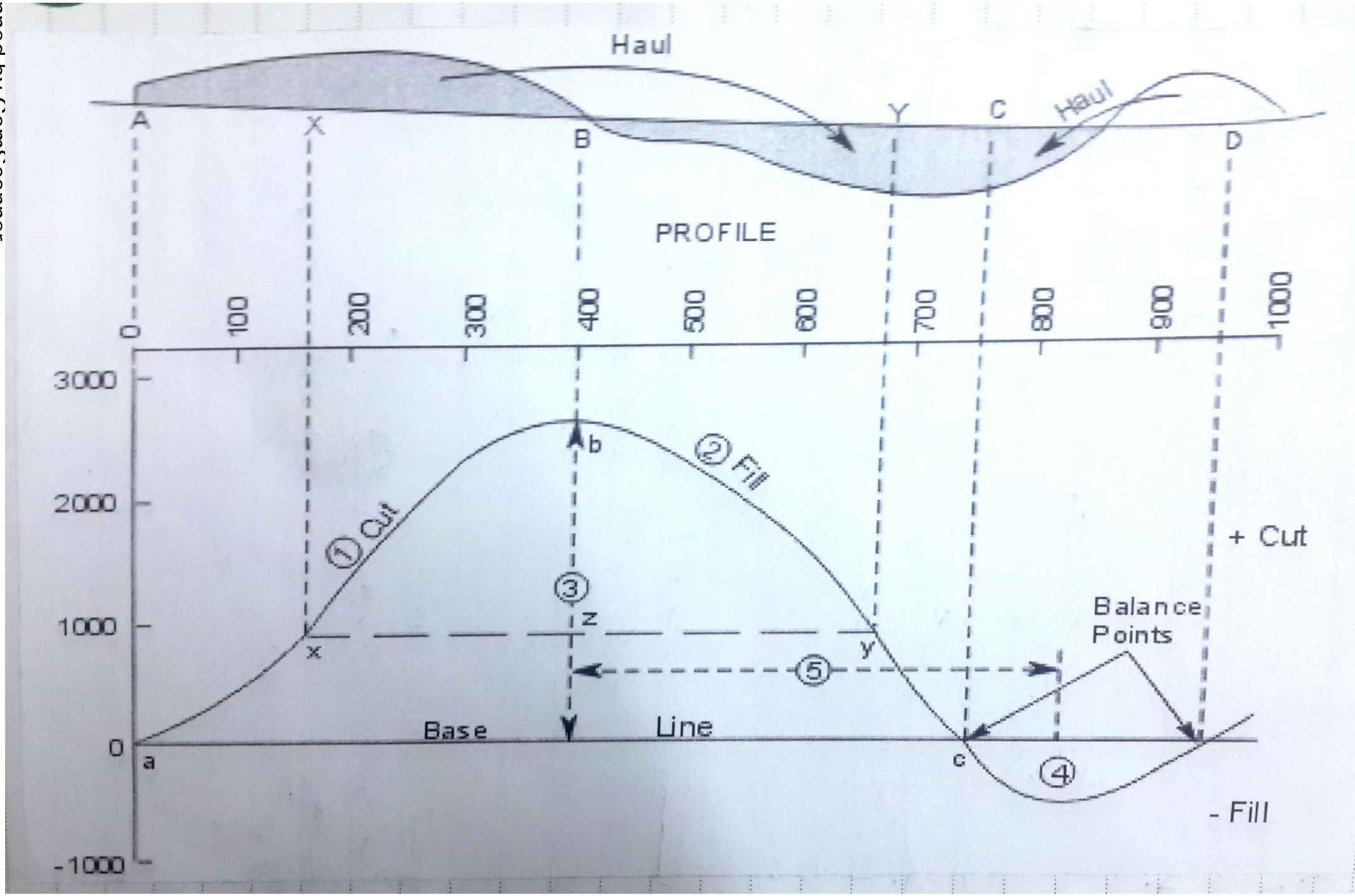
- إذا كانت الارض السلوب الها عالي رح يكون منها cut كثر وممكن ملاحظة ذلك من السلوب للخط في الـ mass haul diagram حيث رح يكون عالي السلوب، الـ cut وممكن!
- الطم يكونة من اليسار لليمين او من اليمين لليسار حسب الكلفة والقرب.











/ /

* Estimating of Nombure of lanes:-

ADT = Average daily traffic → محسوب/مقاسة خلال أقل من سنة

AADT = Anual Average daily traffic → محسوبة/مقاسة خلال أكثر من سنة

- يتم استخدام tube يوضع على طريق فيقوم بعد السيارات المارة عليه، نقوم بتقسيم عددها على عدد أيام تلك الفترة فنحصل على ADT أو AADT
- يتم تقسيم المدة إلى ساعات ويتم النظر لعدد السيارات عند ساعات ذات الترتيب الثلاثين [30th hours]، وأكثر ساعة حققت عدد سيارات هي التي نعتمد عدد سياراتها في التصميم ← Peak hour
- نقوم بتقسيمها إلى أجزاء (أرباع مثلاً) ونرى كم كانت عدد سيارات [وأكبر عدد سيارات مرت خلال الجزء من تلك الساعة الثلاثين × عدد الأجزاء] يمثل الـ capacity للطريق.
- نقيس كل ذلك على مسار واحد [one direction] لأن حركة السير تكثر حسب الوقت على اتجاه واحد، مثلاً في الصباح الناس تذهب إلى الدوام فتشغل الاتجاه المناسب لذلك وعكس مساءً.

Peak direction

ex: design period = 20 year

ADT = 5000 ve in the 1st year

normal growth = 50% → السير الطبيعي

generated traffic = 30% → زيادة السير نتيجة فتح طرق حول الطريق

growth due to developing = 20% → زيادة نتيجة تقدم الأمم مع الزمن اقتصادياً

find ADT after 20 years???

5000 × 50% + 5000 × 30% + 5000 × 20% = 5000

5000 + 5000 = 10000 = New ADT

Ex: AADT = 10000 veh. and the percentage of the 30th hour is 20% of the AADT for both direction and the traffic volume in one direction is (60%) so find no. of lanes if the lane capacity is 600 ve/h ???

DDHV: Directional design hourly volume [ve/hr]

= 60% x 20% x 10,000

= 1200 ve/hr

no. of lanes = $\frac{\text{DDHV}}{\text{Lane capacity}} = \frac{1200 \text{ ve/hr}}{600 \text{ ve/hr}}$

= (2) Lanes in each direction

= 4 Lane Highway

Location analysis

/ /

- Road to location is based on:
  1- Topography (avoid difficult topography)
  2- obstructions (avoid ruins, buildings, water resources ---)
  3- soil (avoid weak soil)
  4- plilical
  5- avoid aquizition of land
  6- Environment (Nois pollution)
  7- Economic (cheepest is best) (lowest cost)
  8- sometimes, horizantal curves are provided backset drivers dent.

- phases of rout location:-
  1- office study
  2- premelinary survey
  3- find survey
  4- use of map, computer map, arial map

- Design process:
  1- choose more than one alternative to the highway and choose best.
  2- Draw section to define the bravers limit of the road.
  ~~3~~ (Right of way) direction (side steps, back slopes, ---)
  3- define horizantal aligment (H-curves)
  4- draw the existing ground profile.
  5- ~~Describe~~ determine the grade.
  6- design the vertical curve (profile elevation, BC, EC---)
  7- Draw cross section of selected stations.
  8- determine volumes of cut & fill earthwork.
  - To calculate earth work volume, use the average in area.

9- develope mass haul diagram to show the accumulation of the total earth work in the relation with the horizontal location along the job (stations).
10- determine the draing (skuctur, bridge, pipes) locations
11- design the pipes or bridges cross sectional area to accomidate the expected water flow.

● some consideration points, when designing :-
1- avoid sharp & short curves, short radius for H-curve. (will cause problems regarding sight distance)
2- avoid compound curves if possible.
3- avoid brupt reversal of curves.
4- short straight lines between curve shouldn't less the $6 * \frac{V}{}$ and $2 * V$ between reverse curve [H-curves] design speed (ie V = 100 → 6x100 = 600m --- and so on)
Min
5- straight roads with same slope should not be larger than (20 * V) → حتى ما ينعس او يمل السائق
Max
6- Horizontal & vertical curves should be avoided at intersection.
7- It's prefered to be parallel to the contour lines rather than perpendicular.
8- slope should not be larger than 3% for level terrain, 4% for hilly areas and 7% for mountain area [rural roads].
9- you should avoid fill at steap sharp H.curve
10- The BC and EC of two consecunce H-curve should not concide
11- change of grade from plus to minus should be in cut (crest v. curve) and change from minus grade to plus should be placed in fill

12- sharp H-curve shouldn't be near the middle of the sag or crest of v-curve.

[redacted]

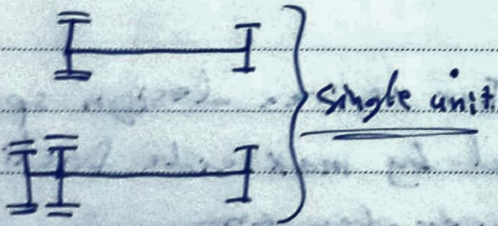
Design standard :-

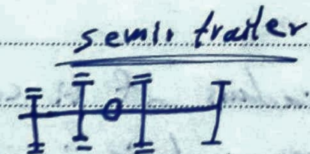
vehicles are classified by AASHTO into four main categories

1- passenger cars

2- Buses

3- Trucks





4- Recreational vehicles

- لهو صعب منها الإدارة
- هي سيارة بتجر قارب او كرفانة،

Design vehicle:-

- when designing, parking lot passenger car is used.
- " " intersection of local road, single unit truck is used.
- when designing intersection of highway city streets (collectors) buses are used.
- when designing intersection of freeway ramp semi-trailer

vehicle characteristics:

Design vehicle:- It's a certain characteristic in the vehicle which is important for the geometric design

1 → weight → structural design of pavement and bridges.
2 → vehicle length → parking stall length
→ plat form length
3 → width → lane width
→ parking stall width
→ lateral clearance
4 → Height → vertical clearance
5 → wheal Base → Lateral clearance
→ intersection edge radius

a. minimum radius of H-curve for a given design speed
min curve radius is limited by max. side friction which is based on ~~max~~ super elevation

b. max superelevation

c. Min gradient, it's limited by the need to provide drainage.

d. Minimum length of V. curve, it's limited by SSD, appearance, comfort

Travel Lanes:

- The standard width is (3.6 m)(12 ft) and the min is (2.7 m) (9 ft)
- Lanes are wider than 3.6 m are provided at the curves to account heavy vihicles.
- the width and number of lanes depends on:
  1- volume of traffic
  2- design speed

categories of Highway:-

1- Two-lane highway width = 7.2 m + shoulders width
2- Three lane " : maybe used in the following cases
   a. Two lane in one direction and one lane in the other direction.
   b. The third lane maybe used alternately
   c. for climbing lanes
   d. for Left turns only (urban areas)
3- four or more lane highways should be divided by median strip.

Pavement Crown

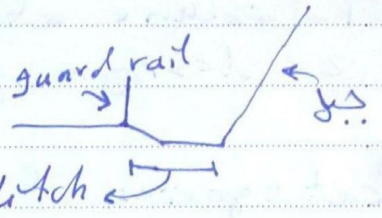
- Raising the centerline of the roadway above the pavement edge for drainage purposes
- Recommended values (1.5-2%) slope proper drainage system at the edge should be provided
- for one way streets or divided road (with median) may not have a crown in the center of the road.

sidewalk:

They are provided in urban roads on both sides also when pedestrain traffic is high // In urban or rural areas the max

width is 1.2m in residential areas, and range (4-8)f- in commercial areas.

- Guard Rails :-
  - they should be provided when:-
    1- Fill > 2.4 m high
    2- sudden change in alignment (sharp curve)
    3- In location near side ditches

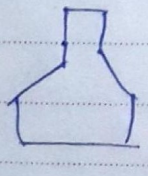


Types of guard rails:-

1) w-beam

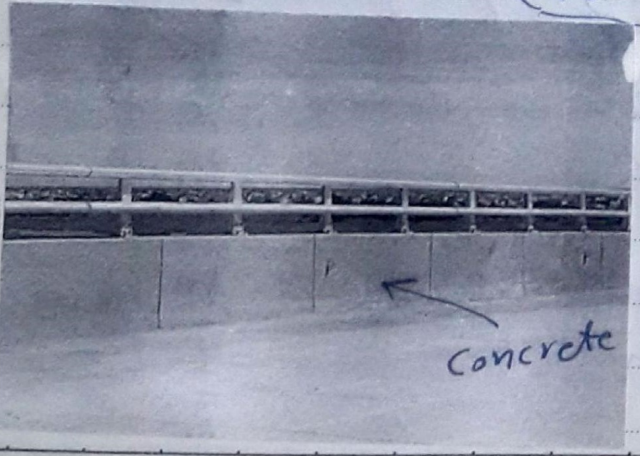
2) Cables "flexible"

3) Concrete



Guard Rail should be flexible to reduce damage if there is collisions

- In urban road, curb stones are used, they should be between (15-20)cm high



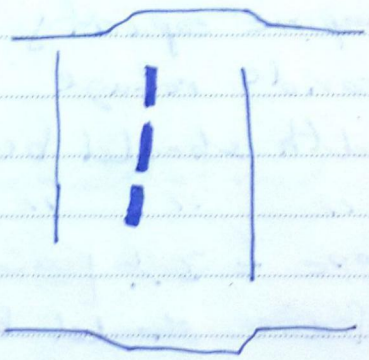
Median (~~ ~~) :- it's the section of a divided highway that seperates the lanes in opposing directions.

The function of median include :-

1- seperate opposing traffic
2- Providing storage areas for left turning and u-turn vehicles.
3 - providing refuge for pedestrains.
4- Reducing the effect of headlight glare.

median should be 1.2 m - 18 m

median can be a: a- Raised
b - flushed
c - depressed



- Raised median are used in urban road
- flused median are used in " " and Freeway with median barries
- depressed medians are used in freeway & the are more effective in draing surface water.

- objective for providing Horizatal curves:
  1- To keep the driver alert
  2- To avoid any obstruction, building, weak soil
  3- To avoid difficult topography
  4- To avoid acquistion (شراء) of lands

- shoulders..
  They are provided for:.
  1- For safe operation of traffic
  2- They increase sight distance on H curves.
  3- They provide structural support for the pavement.
  4- Improve capacity
  5- provide refuge for stalled vehicles or emergency.
  - width should be > 3m
  - " " " > 1.2m in mountain areas
  - slope = 3 % [3:100 → 1:33]
  - surface should be rough compared to the main road

- Right of way:-
  - It's the land acquired along the road's alignment by the highway organization (هيئة الطرق / وزارة)
  - The right of way depends on the important of the road sufficient right of way should be acquired In order to:.
    1- Avoid the expense of purchasing developed properties.

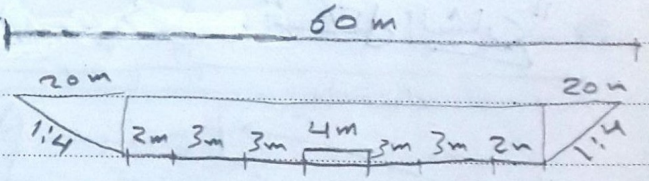
2- For side slopes and Backslope
3- provide draing systems
4- visibility consideration on H-curve.
5- width of land required for future development

- Recommended values:-
- (40-60) ft for 2-lane highway (collector)
- minimum (80) ft for arterial 2-lane
- 4 lane undevided arterial (64-108) ft
- divided from (120-300) ft depending on number of lanes.

- you can calculat exactly the value of Right of way:-

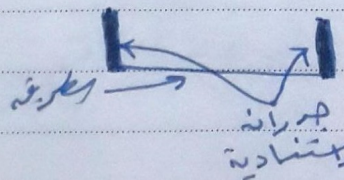
Ex: 4 lane each lane 3m → 12m
Median = 4m → 4 m
soulder = 2m → 4m
20 m = width of road

Fill = 5 m (if side slope = 1:4) → 20x2 = 40

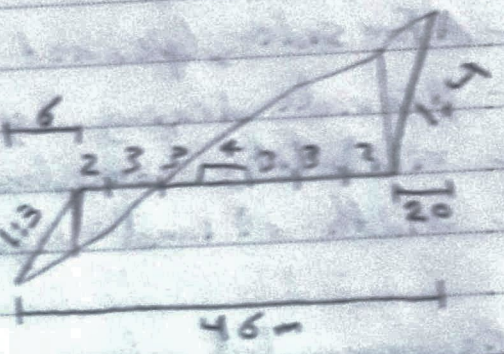


20+40 = 60m
∴ The required Right of way = 60 m

معلومة: إذا الدولة لم تكن تمتلك من اراضي الـ sideslope والـ Backslope ولم تشريع عليها من أجل الأمان أن تضع جدران إستنادية على حواف الطريق والابتعاد عن الميول الجانبية تماماً.



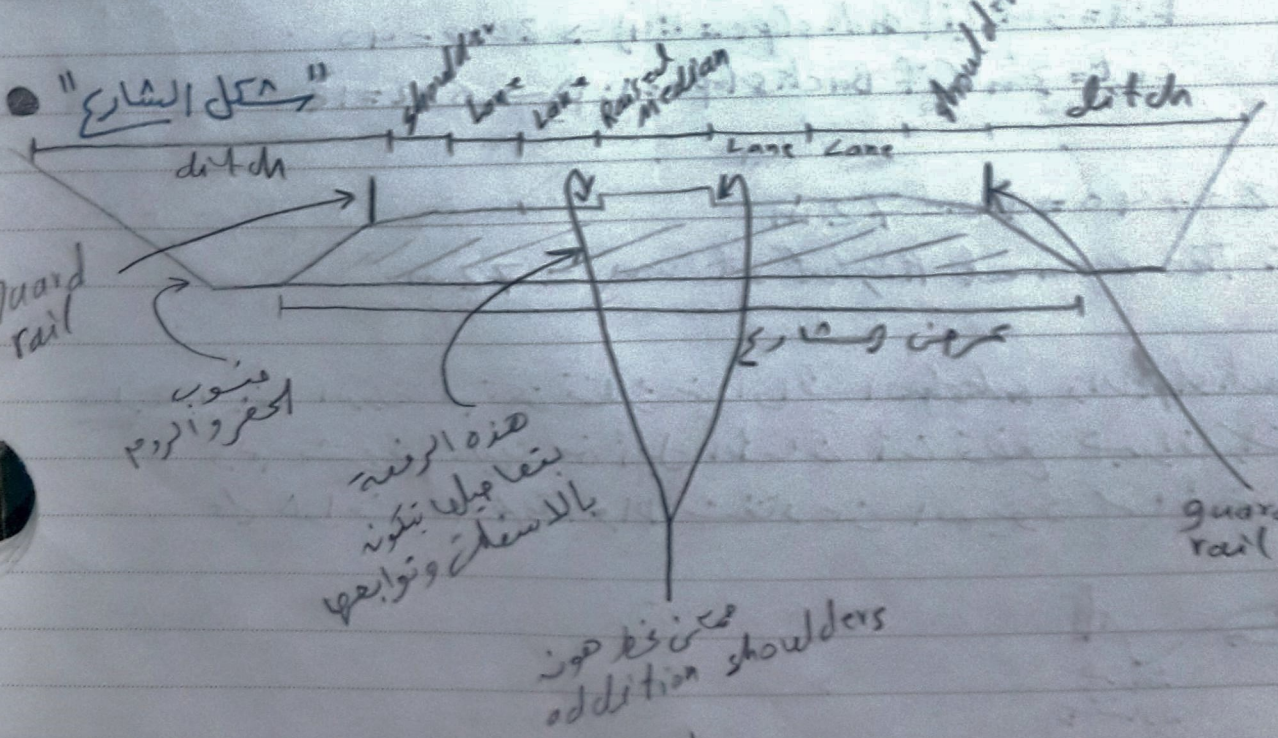
ex: median = 4m
4 lane - 3m each lan = 12m
each shoulders = 2m ⇒ 4m
Back slope (1:4) ⇒ cut = 5 ⇒ 20m
side slope (1:2) ⇒ fill 3 ⇒ 9m



4+12+4 = 20m ⇒ width of road
20+20+9 = 49m ⇒ Right of road

- Drainge ditches:-
قناة موجودة بين الـ cut وحافة الطريق، وتصنع من تجميع مياه الأمطار.
- Flate bottom are prefered above V-shaped.

- "شكل الشارع"



• طبقات الطريق :-

Surface	5cm	→ Hot Mixed Asphalt
Base	10 cm	
sub base	15 cm	

• حساب الكلفة :-

Iteam	unit	price/unit	Quantity	Total Price
Leveling	m^2			
cut	m^3	3 Jd		
fill	m^3	3.5 Jd		
sub base	m^2 or m^3	2 Jd		
base	m^2	2.5 Jd		
prime coat (MC)	Kg	0.5 Jd		
Hot Mix Asphalt (HMA)	m^2/m^3/tonn	5 Jd		

← الاسعار للمثال (مش ارقام حقيقية)

- ال "sub base" نحسبها بال m^3 ولكن إذا اعتبرنا ان سماكة الطبقة ثابتة فيمكن تصبح حسب مساحة سطحها فقط اي بال m^2.

- ال "MC" هي طبقة سائلة نضعها على ال Base لكي تمنع طبقات الطريق وبالتالي تقلل من امتصاصهم لا مواد ال "HMA".

- يُقاس ال HMA بالطن إذا كان شارع قديم وأردنا رصفه من جديد و " بال m^3 او m^2 اذا كان شارع جديد ويراد رصفه للمرة الاولى

Cost Of Items

iteam	unit	unit price	quantity	item price
leveling	m2	0.5	-	-
cut	m3	3	62133.6	186400.8
fill	m3	3.5	26338.2	92183.77
sub base (15 cm)	m3	2	2580	5160
base (10 cm)	m3	2.5	1720	4300
prime road (1.5kg/m2)	kg	0.5	2580	1290
hot mix asphilt (5 cm)	m3	5	860	4300
				293634.57

Parking Studies

One of the important consideration in traffic operations is the parking, because the vehicles which operate on street and hwy have a terminal point requiring parking.

The parking facilities can be grouped in the following two types.

① Kerb or on-street parking
② off-street parking

[1] Kerb or on-street parking:-

the disadvantages of on-street parking:

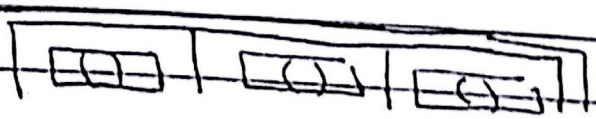
[A] The safety of variance classes of road users is adversly effected (increase road accidents particularly pedestrians).

[B] Impead traffic flow and reduce their speed.

[C] Decrease the road capacity, increase journy time and delay.

the on-street parking can be permited in specified measures; it is either

[A] Parallel parking



[B] Angular Parking:

(*) Angular Parking is designed under the following conditions:

[1] Inside streets heavey good sight distance.

[2] Local Streets.

[3] One-Way Streets

[4] Low traffic volume

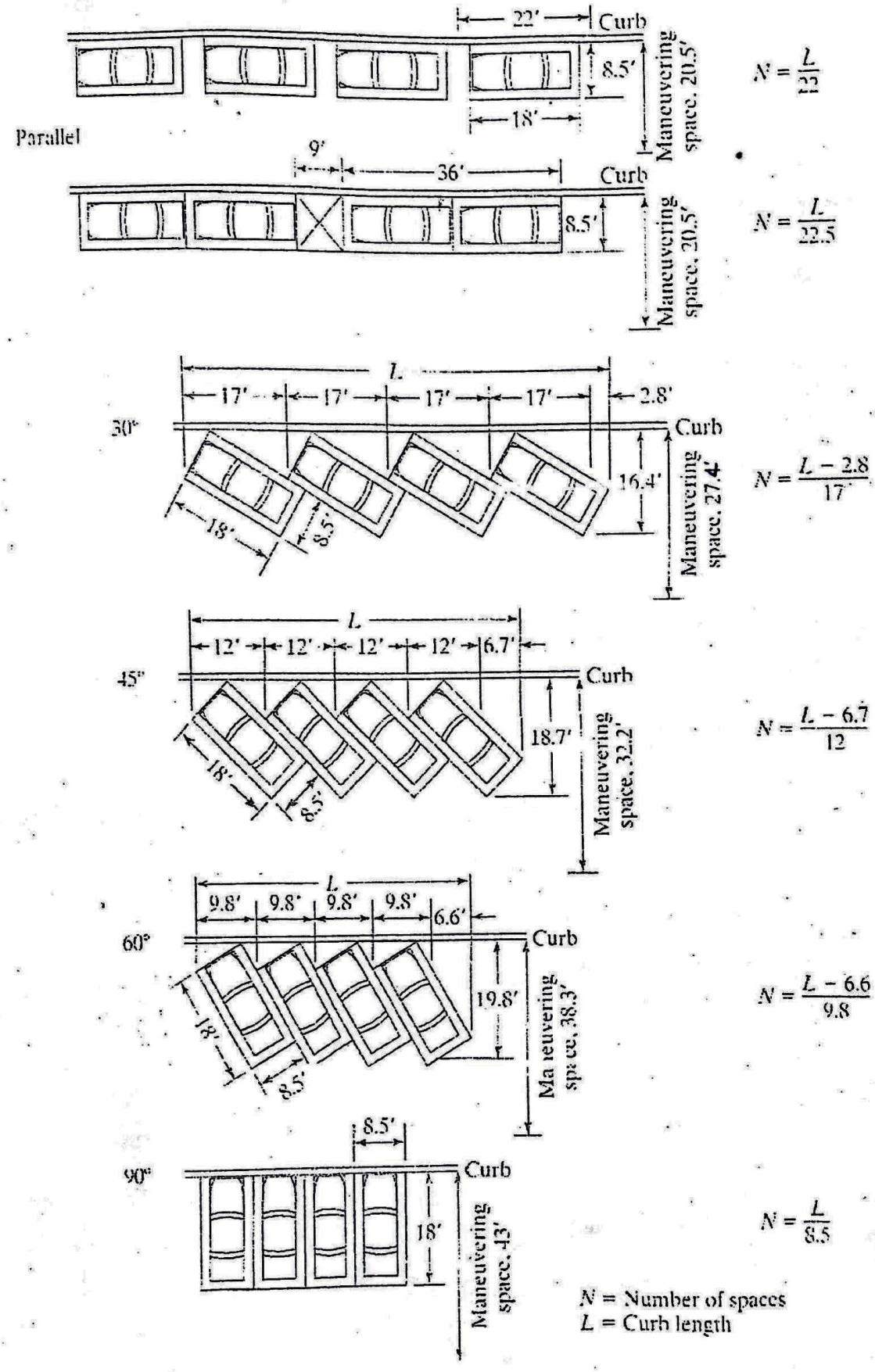
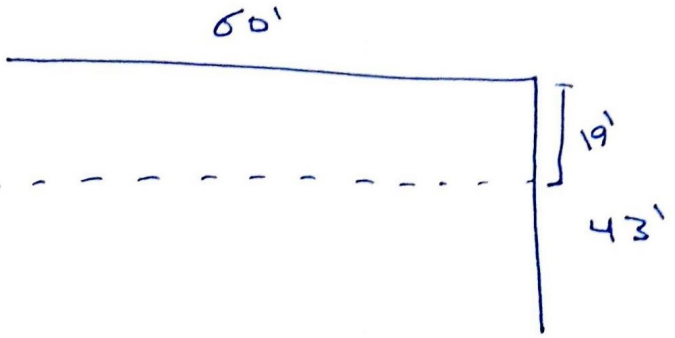


Figure 12-19 Curb Parking Geometry (Carter and Homburger, 1978).



- بدي اعمل two lane كل واحد 12' مخلي الحيز للمصفات (parking) باقي (43 - 24 = 19')
- بقدر اعمل فيه 90° parking وبزيد قدام وبيسع لـ ($\frac{60'}{8.5'}$ = 7 مركبات)
- بقدر اعمل فيه مصفين parallel ($17' = 2 \times 8.5'$) وبزيد قدامين (ft) وبيسع لـ ($2 \times \frac{60}{22.5}$ = 5 مركبات) بس طبعاً مصفين واحايدين

- وبقدر اشياء ثانية بختار الاشيا اللي بتعطيني أكبر عدد سيارات (N)
- كل ما زادت الزاوية ← بزيد عرض الطريقة اللازم لاستقبال المصف.
← بزيد (N).

سؤال:

two lane highway (12' each lane

$\therefore 58 - 2 \times 12 = 34'$

$$V_w = \frac{(N_e + O_w - P_w)\,60}{T_e + T_w} = \frac{(79.50 + 1.25 - 0.875)\,60}{2.85 + 3.07} = 809.5 \quad \text{(or 810 veh/h)}$$

- Similarly, calculate the volume in the eastbound direction:

$$V_e = \frac{(82.25 + 1.00 - 1.50)\,60}{2.85 + 3.07} = 828.5 \quad \text{(or 829 veh/h)}$$

- Find the average travel time in the westbound direction:

$$\bar{T}_w = 3.07 - \frac{(1.25 - 0.875)}{810}\,60 = 3.0 \text{ min}$$

- Find the average travel time in the eastbound direction:

$$\bar{T}_e = 2.85 - \frac{(1.00 - 1.50)}{829}\,60 = 2.9 \text{ min}$$

Methods Not Requiring a Test Vehicle

This category includes the license-plate method and the interview method.

License-Plate Observations. The license-plate method requires that observers be positioned at the beginning and end of the test section. Observers can also be positioned at other locations if elapsed times to those locations are required. Each observer records the last three or four digits of the license plate of each car that passes, together with the time at which the car passes. The reduction of the data is accomplished in the office by matching the times of arrival at the beginning and end of the test section for each license plate recorded. The difference between these times is the traveling time of each vehicle. The average of these is the average traveling time on the test section. It has been suggested that a sample size of 50 matched license plates will give reasonably accurate results.

Interviews. The interviewing method is carried out by obtaining information from people who drive on the study site regarding their travel times, their experience of delays, and so forth. This method facilitates the collection of a large amount of data in a relatively short time. However, it requires the cooperation of the people contacted, since the result depends entirely on the information given by them.

PARKING STUDIES

Any vehicle traveling on a highway will at one time or another be parked for either a relatively short time or a much longer time, depending on the reason for parking. The

provision of parking facilities is therefore an essential element of the highway mode of transportation. The need for parking spaces is usually very great in areas where land uses include business, residential, or commercial activities. The growing use of the automobile as a personal feeder service to transit systems ("park-and-ride") has also increased the demand for parking spaces at transit stations. In areas of high density, where space is very expensive, the space provided for automobiles usually has to be divided between that allocated for their movement and that allocated for parking them.

Providing adequate parking space to meet the demand for parking in the CBD may necessitate the provision of parking bays along curbs, which reduces the capacity of the streets and may affect the level of service. This problem usually confronts a city traffic engineer. The solution is not simple, since the allocation of available space will depend on the goals of the community, which the traffic engineer must take into consideration when trying to solve the problem. Parking studies are therefore used to determine the demand for and the supply of parking facilities in an area, the projection of the demand, and the views of various interest groups on how best to solve the problem. Before we discuss the details of parking studies, it is necessary to discuss the different types of parking facilities.

Types of Parking Facilities

Parking facilities can be divided into two main groups: on-street and off-street.

On-Street Parking Facilities

These are also known as curb facilities. Parking bays are provided alongside the curb on one or both sides of the street. These bays can be unrestricted parking facilities if the duration of parking is unlimited and parking is free, or they can be restricted parking facilities if parking is limited to specific times of the day for a maximum duration. Parking at restricted facilities may or may not be free. Restricted facilities may also be provided for specific purposes, such as to provide handicapped parking or at bus stops or loading bays.

Off-Street Parking Facilities

These facilities may be privately or publicly owned; they include surface lots and garages. Self-parking garages require that drivers park their own automobiles; attendant-parking garages maintain personnel to park the automobiles.

Definitions of Parking Terms

Before discussing the different methods for conducting a parking study, it is necessary to define some terms commonly used in parking studies, including *space-hour, parking volume, parking accumulation, parking load, parking duration,* and *parking turnover.*

1. **A space-hour** is a unit of parking that defines the use of a single parking space for a period of 1 hr.
2. **Parking volume** is the total number of vehicles that park in a study area during a specific length of time, usually a day.
3. **Parking accumulation** is the number of parked vehicles in a study area at any specified time. These data can be plotted as a curve of parking accumulation against time, which shows the variation of the parking accumulation during the day.

4. The parking load is the area under the accumulation curve between two specific times. It is usually given as the number of space-hours used during the specified period of time.
5. Parking duration is the length of time a vehicle is parked at a parking bay. When the parking duration is given as an average, it gives an indication of how frequently a parking space becomes available.
6. Parking turnover is the rate of use of a parking space. It is obtained by dividing the parking volume for a specified period by the number of parking spaces.

Methodology of Parking Studies

A comprehensive parking study usually involves (1) inventory of existing parking facilities, (2) collection of data on parking accumulation, parking turnover, and parking duration, (3) identification of parking generators, and (4) collection of information on parking demand. Information on related factors, such as financial, legal, and administrative matters, may also be collected.

Inventory of Existing Parking Facilities

An inventory of existing parking facilities is a detailed listing of the location and all other relevant characteristics of each legal parking facility, private and public, in the study area. The inventory includes both on- and off-street facilities. The relevant characteristics usually listed include the following:

- Type and number of parking spaces at each parking facility
- Times of operation and limit on duration of parking, if any
- Type of ownership (private or public)
- Parking fees, if any, and method of collection
- Restrictions on use (open or closed to the public)
- Other restrictions, if any (such as loading and unloading zones, bus stops, or taxi ranks)
- Probable degree of permanency (can the facility be regarded as permanent or is it just a temporary facility?)

The information obtained from an inventory of parking facilities is useful both to the traffic engineer and to public agencies, such as zoning commissions and planning departments. The inventory should be updated at regular intervals of about four to five years.

Collection of Parking Data

Accumulation. Accumulation data are obtained by checking the amount of parking during regular intervals on different days of the week. The checks are usually carried out on an hourly or 2-hr basis between 6:00 a.m. and 8:00 p.m. The selection of the times depends on the operation times of land-use activities that act as parking generators. For example, if a commercial zone is included, checks should be made during the times when retail shops are open, which may include periods up to 9:30 p.m. on some days. The information obtained is used to determine hourly variations of parking and peak periods of parking demand. (See Figure 4.16.)

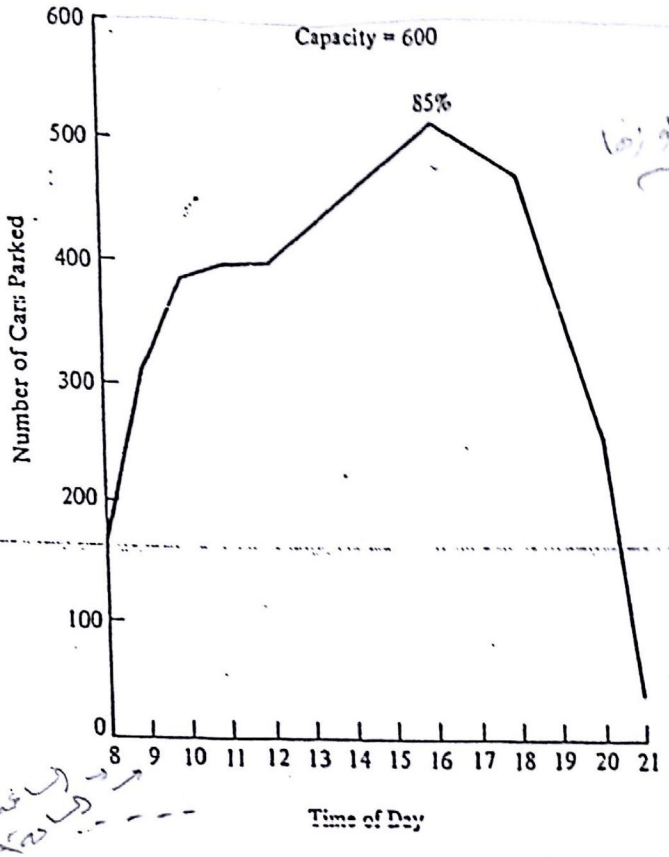


Figure 4.16 Parking Accumulation at a Parking Lot

Turnover and Duration. Information on turnover and duration is usually obtained by collecting data on a sample of parking spaces in a given block. This is done by recording the license plate of the vehicle parked on each parking space in the sample at the ends of fixed intervals during the study period. The length of the fixed intervals depends on the maximum permissible duration. For example, if the maximum permissible duration of parking at a curb face is 1 hr, a suitable interval is every 20 min. If the permissible duration is 2 hr, checking every 30 min would be appropriate. Turnover is then obtained from the equation

$$T = \frac{\text{number of different vehicles parked}}{\text{number of parking spaces}} \tag{4.11}$$

Identification of Parking Generators

This phase involves identifying parking generators (for example, shopping centers or transit terminals) and locating these on a map of the study area.

Parking Demand

Information on parking demand is obtained by interviewing drivers at the various parking facilities listed during the inventory. An effort should be made to interview all drivers using the parking facilities on a typical weekday between 8:00 a.m. and 10:00 p.m. Information sought should include (1) trip origin, (2) purpose of trip, and (3) driver's destina-

tion after parking. The interviewer must also note the location of the parking facility, the times of arrival and departure, and the vehicle type.

Parking interviews can also be carried out using the postcard technique, in which stamped postcards bearing the appropriate questions and a return address are handed to drivers or placed under windshield wipers. When this technique is used, usually only about 30 to 50 percent of the cards distributed are returned. It is therefore necessary to record the time and the number of cards distributed at each location, because this information is required to develop expansion factors, which are later used to expand the sample.

Analysis of Parking Data

Analysis of parking data includes summarizing, coding, and interpreting the data so that the relevant information required for decision making can be obtained. The relevant information includes the following:

- Number and duration for vehicles legally parked
- Number and duration for vehicles illegally parked
- Space-hours of demand for parking
- Supply of parking facilities

The analysis required to obtain information on the first two items is straightforward; it usually involves simple arithmetical and statistical calculations. Data obtained from these items are then used to determine parking space-hours.

The space-hours of demand for parking are obtained from the expression

$$D = \sum_{i=1}^{N} (n_i t_i) \tag{4.12}$$

where

D = space vehicle-hours demand for a specific period of time
N = number of classes of parking duration ranges
t_i = midparking duration of the ith class
n_i = number of vehicles parked for the ith duration range

The space-hours of supply are obtained from the expression

$$S = f \sum_{i=1}^{N} (t_i) \tag{4.13}$$

where

S = practical number of space-hours of supply for a specific period of time
N = number of parking spaces available
t_i = total length of time in hours when the ith space can be legally parked on during the specific period
f = efficiency factor

The efficiency factor f is used to correct for time lost in each turnover. It is determined on the basis of the best performance a parking facility is expected to produce. Efficiency

Example: A parking garage has 200 spaces parking duration (t) is 2 hrs.

7am - 7pm

space-hr available = 12*200 = 2400 sp-hr

# of vehicles = $\frac{2400}{2}$ = 1200 vehicles could park in the garage.

efficiency factor (0-1.0) *2400

↳ if it is 0.9 → # of vehicles = 0.9*1200 = 1080

parking Turnover:

parking garage have 200 P. spaces, 450 vehicles using the garage. Final parking turnover.

P. Turnover = $\frac{450}{200}$ = 2.25 veh/spaces

previous example p. Turnover = $\frac{1200}{200}$ = 6

$$\left[\begin{matrix}\text{Factored}\\ \text{Required}\\ \text{vehicles}\\ \text{to park}\end{matrix}\right] = \frac{(\#\text{spaces}) \times (\text{work hours}) \times (E.f)}{(\text{parking duration})}$$

{هذا القانون # مجرد - إستنتاج}

Five Apple

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Example: In a parking garage which have a capacity of (300) p-spaces and open from 7am-7pm, there are 480 vehicles parked daily. 30% of the vehicles parked (8 hrs), 50% parked for (6 hrs) and 20% parked for (2 hrs). Determine whether there is a need to provide for additional parking spaces for the garage.

Sol:

* $480 * \frac{30}{100} = 144$ vehicles park for 8 hrs

$\Rightarrow$ space-hour required $= 144 * 8 = 1152$ sp-hr

* $480 * \frac{50}{100} = 240$ vehicles park for 6 hrs

$\Rightarrow$ space-hr required $= 240 * 6 = 1440$ sp-hr

* $480 * \frac{20}{100} = 96$ vehicle park for 2 hrs

$\Rightarrow$ space required $96 * 2 = 192$ sp-hr

space hr required $= 192 + 1440 + 1152$

$= \boxed{2784 \text{ sp-hr}}$

$\rightsquigarrow$ space-hr available $= 300 * 12 = \underline{3600 \text{ sp-hr}}$

$3600 > 2784$

there is no need

factors should therefore be determined for different types of parking facilities—for example, surface lots, curb parking, and garages. Efficiency factors for curb parking, during highest demand, vary from 78 percent to 96 percent; for surface lots and garages, from 75 percent to 92 percent. Average values of f are 90 percent for curb parking, 80 percent for garages, and 85 percent for surface lots.

Example 4.7 Space Requirements for a Parking Garage

The owner of a parking garage located in a CBD has observed that 20 percent of those wishing to park are turned back every day during the open hours of 8 a.m. to 6 p.m. because of lack of parking spaces. An analysis of data collected at the garage indicates that 60 percent of those who park are commuters, with an average parking duration of 9 hr, and the remaining are shoppers, whose average parking duration is 2 hr. If 20 percent of those who cannot park are commuters and the rest are shoppers, and a total of 200 vehicles currently park daily in the garage, determine the number of additional spaces required to meet the excess demand. Assume parking efficiency is 0.80.

Solution

- Calculate the space-hours of demand using Eq. 4.12:

$$D = \sum_{i=1}^{N} (n_i t_i)$$

Commuters now being served $= 0.6 \times 200 \times 9 = 1080$ space-hr

Shoppers now being served $= 0.4 \times 200 \times 2 = 160$ space-hr

Total number of vehicles turned away $= \frac{200}{0.8} - 200 = 50$

Commuters not being served $= 0.2 \times 50 \times 9 = 90$ space-hr

Shoppers not being served $= 0.8 \times 50 \times 2 = 80$ space-hr

Total space-hours of demand $= (1080 + 160 + 90 + 80) = 1410$

Total space-hours served $= 1080 + 160 = 1240$

Number of space-hours required $= 1410 - 1240 = 170$

- Determine the number of parking spaces required from Eq. 4.13:

$$S = f \sum_{i=1}^{N} t_i = 170 \text{ space} - \text{hr}$$

- Use the length of time each space can be legally parked on (8 a.m. through 6 p.m. = 10 hr) to determine the number of additional spaces:

$$0.8 \times 10 \times N = 170$$

$$N = 21.25$$

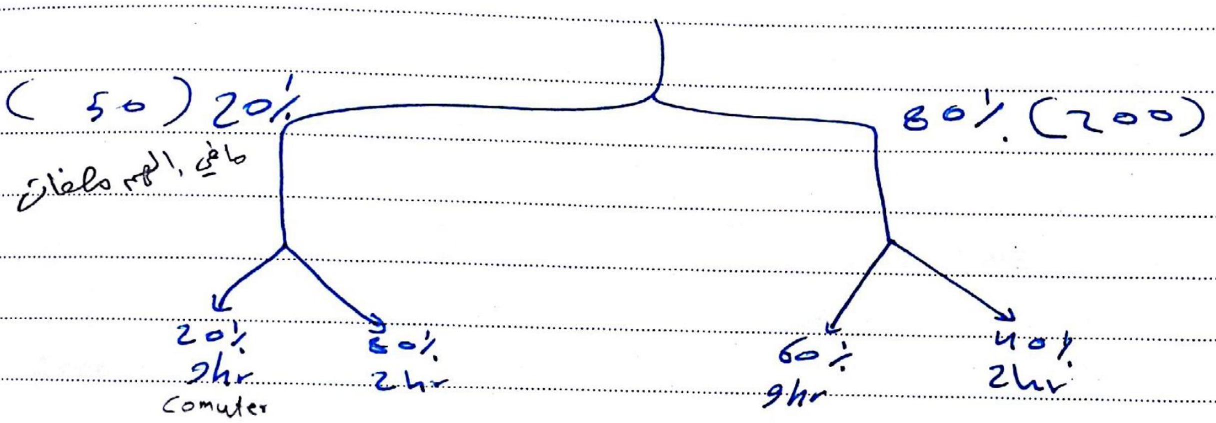
At least 22 additional spaces will be required, since a fraction of a space cannot be used.

/ /

comuter → الي بيقف وبروح كدوامة
(اصطفاف لمدة طويلة)

shopper → متسوق (اصطفاف لمدة قصيرة)

ex 4.7 ⇒ 80% → 200
20% → 50



$\frac{20}{100} \times 50 = 10$ vehicles park 9 hr

space-hour = 9 × 10 = 90 space-hour

$\frac{80}{100} \times 50 = 40$ vehicle park for 2hr.

space hr = 40 × 2 = 80 sp-hr.

Total space hr = 90 + 80 = 170

space required = $\frac{170}{10}$ = 17 space → بدون ال E-factor

E-factor [illegible] = $\frac{170}{10 \times 0.8}$ = 22

AASHTO

Parking generation & supply need.

-L22-

The issue in parking is to determine how many parking spaces are required for a particular development (hospital, hotels, residential areas, ---- etc) the need for parking spaces depend upon many factors:- 1-) The size of Land
2-) Public Transport accessibility
3-) The density of the development

- The Table below shows some of the parking generation specification units.

Type of Land use	prefferd unit	alternative	parking demand
Resedential	per dweling	—	1.2
Shopping center	per 1000 ft^2	—	3.79/1000 ft^2
office	"	—	2.52/1000 ft^2
industrial	per employee	per 1000 ft^2	
Resturant	per seat	"	15.8/1000 ft^2
Hospital	per employee	Per bed	1.79/bed
Parks	per 1000 ft^2	—	3.3/1000 ft^2
Hotels	per unit	—	0.82/Bed

and so on

ex: office area 25000 ft²

25 × 2.5 = 63 parking space

25000 / 1000

(*) Intersections Design:

The general term junction or intersection in where two or more roads cross one another at the same or different elevation.

Types of intersections:

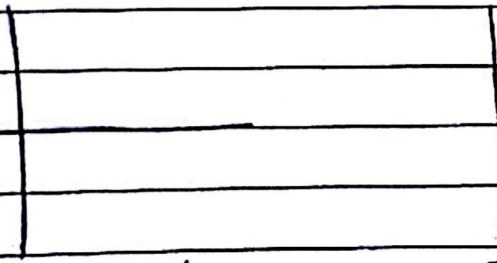
intersections can be grouped in two categories:

[1] At grade intersection. ← على نفس المستوى

[2] Graded-Seperated ← فوق بعض
- with ramp
- without ramp (freeway & Local) الـ

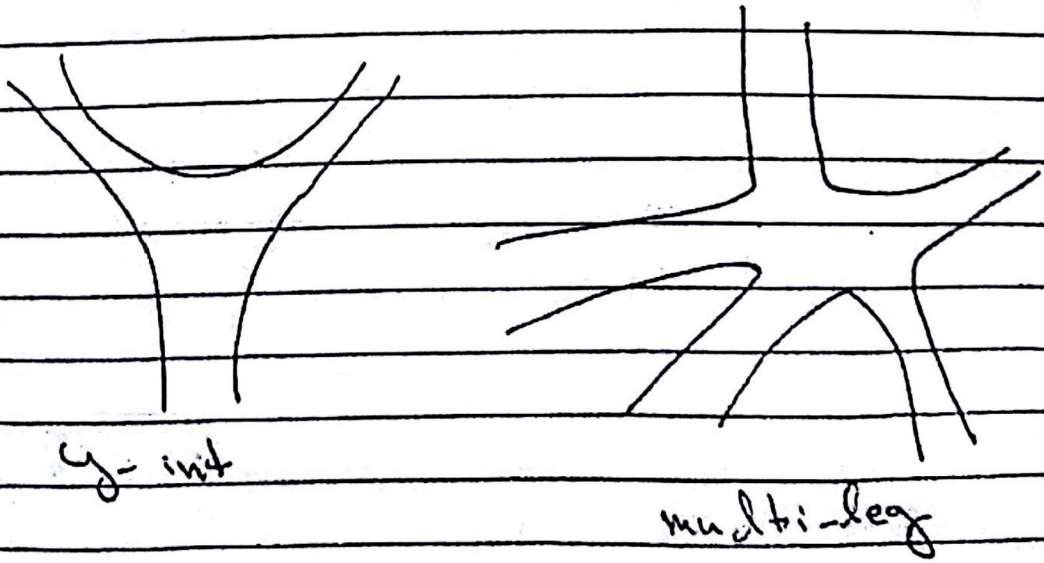
(1) At grade intersection:

This is the most common type of int. and it indicates the road junction at the same elevation.



Cross-intersection

T-int



Y-int

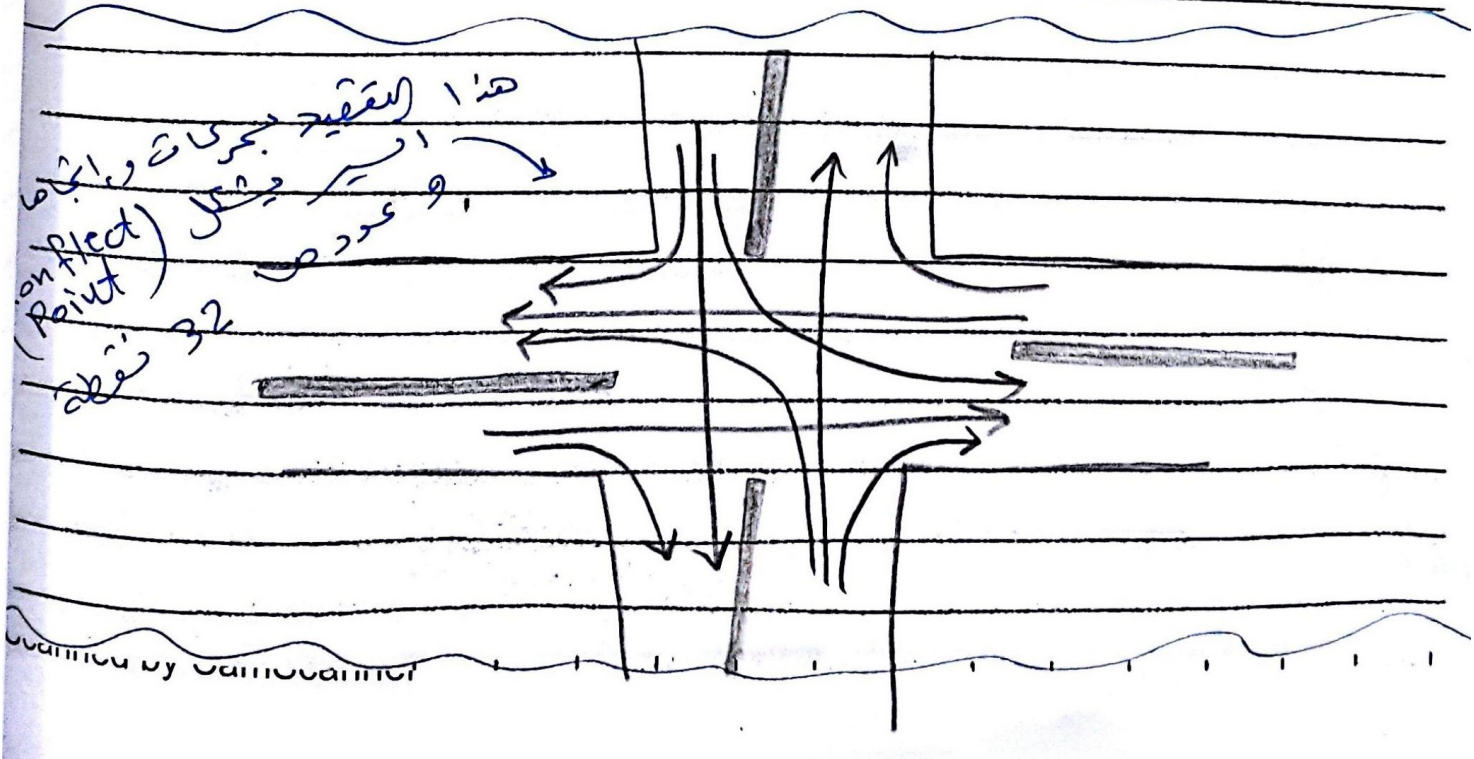
multi-leg

يُفضّل عدم استخدامه Skewed-int
بدّنه يُعيق حركة السّائقات

Flared - cross

declaration lane
تقاطعات

T-Flared



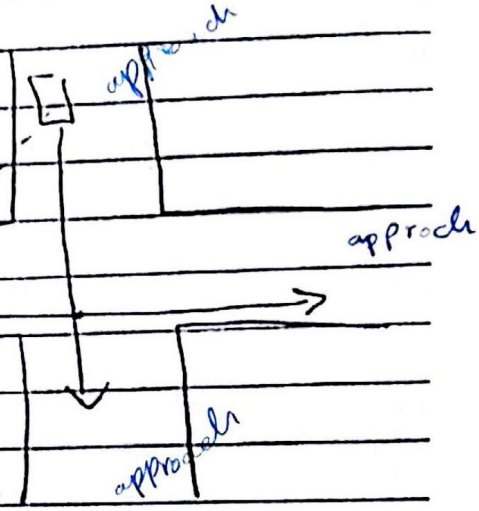
There are three types of at grade int.

1. All-paved int. or unchannaled int.
2. channaled int.
3. Round about.
4. traffic signals

increasing traffic volume

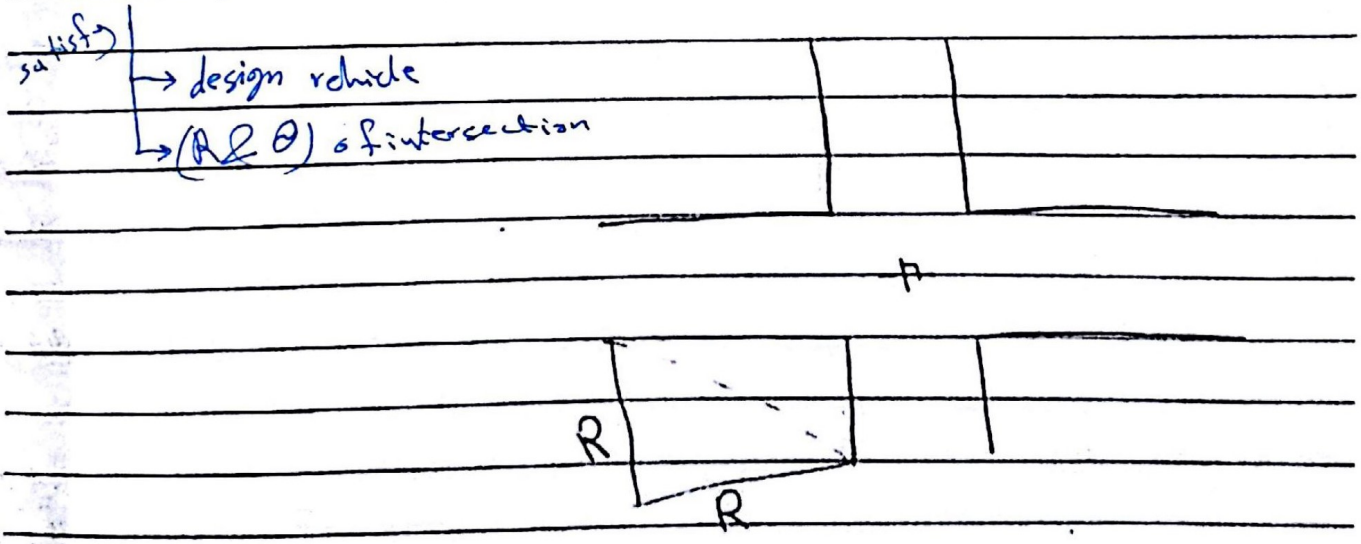
The Design of int. (the curb line) depends on the following:

1) Sight Distance: if the sight distance is limited or short, stop sight or (give-way) sight should be installed (Stop Sight for less important road)

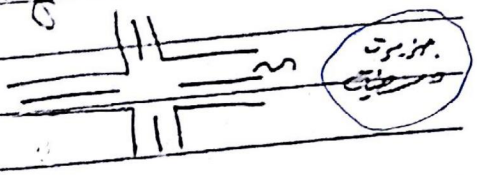


2) Turning radius: depends on the composition of traffic.

satisfy → design vehicle
→ (R & θ) of intersection

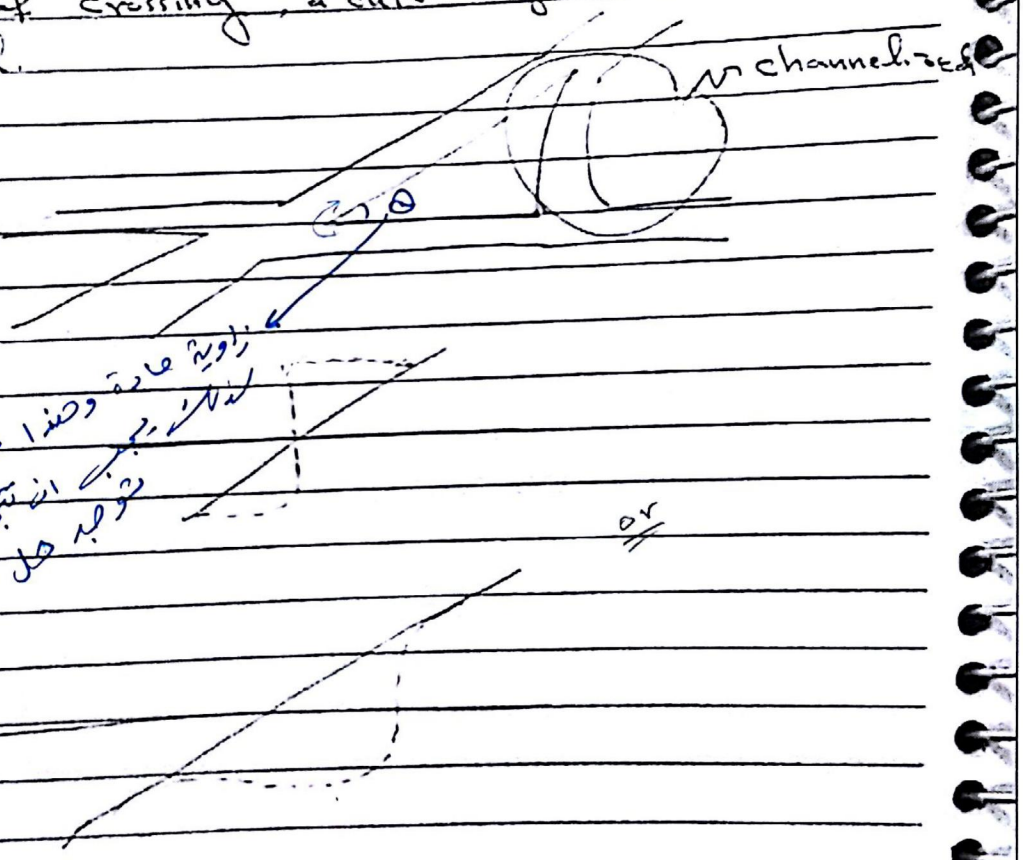


3) Pedestrian Movement (حركة المشاة)
when pedestrian movement is large, it's preferable
to [illegible] the road



4) Reducing accident (safety consideration)
(reducing conflict points).

5) Angle of crossing, acute angle should be
avoided.



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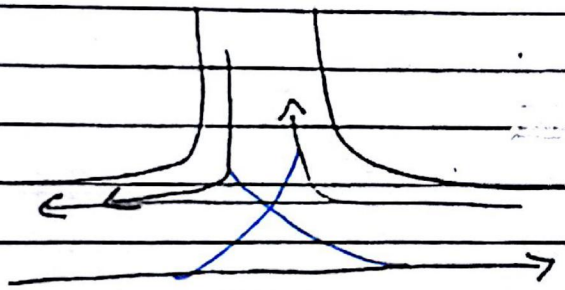
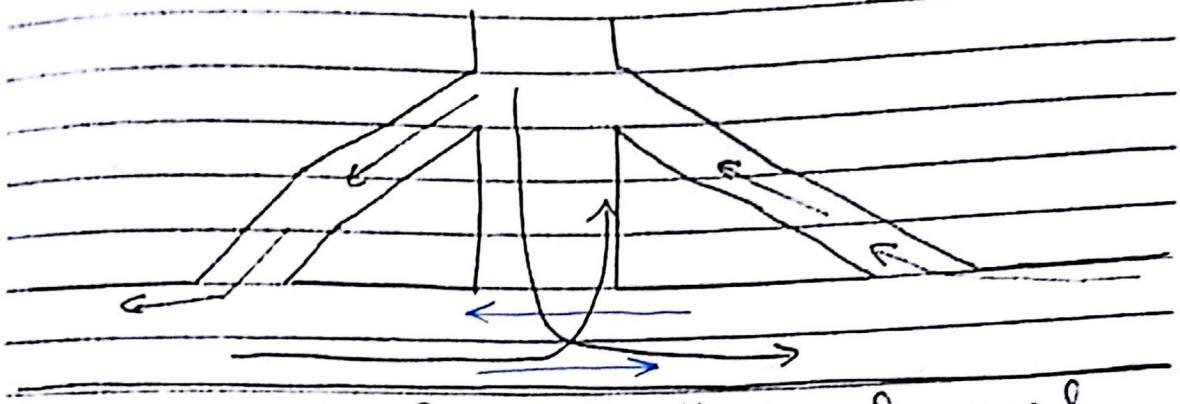
6) Type of intersecting road

* If the traffic volume is low and the crossing road are minor, then simple as all paved int. is used.
* If the traffic increases then flared int. is used.
* If the traffic volume increases more then use channelized int.
* If the delay increases more then round about is used.
* If Round about fail then use traffic singnals
* ⟹ If all that fail then we should use grade seperation.

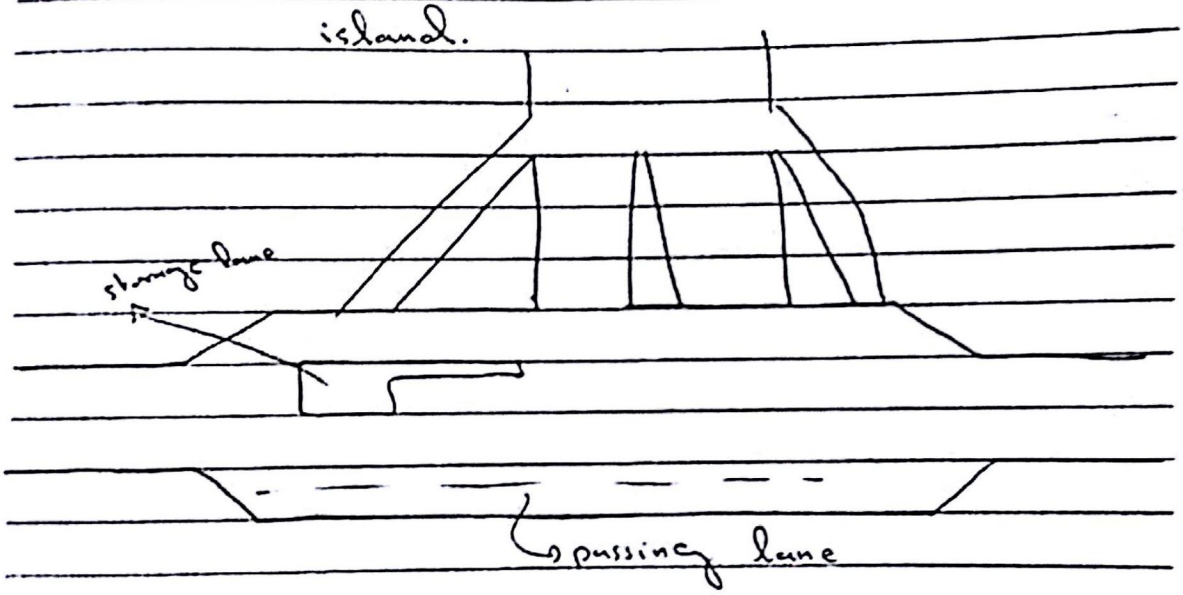


plane (T- int.) used for minor roads. (Local & Local)

T- int. with right turn lane additional Lane is provided to seperate sight turning veh from through vehicle.



Channelized T-int with two divisional island.



Channelized T-int. with right turning, passing lane for through movement and storage lane for left turning.

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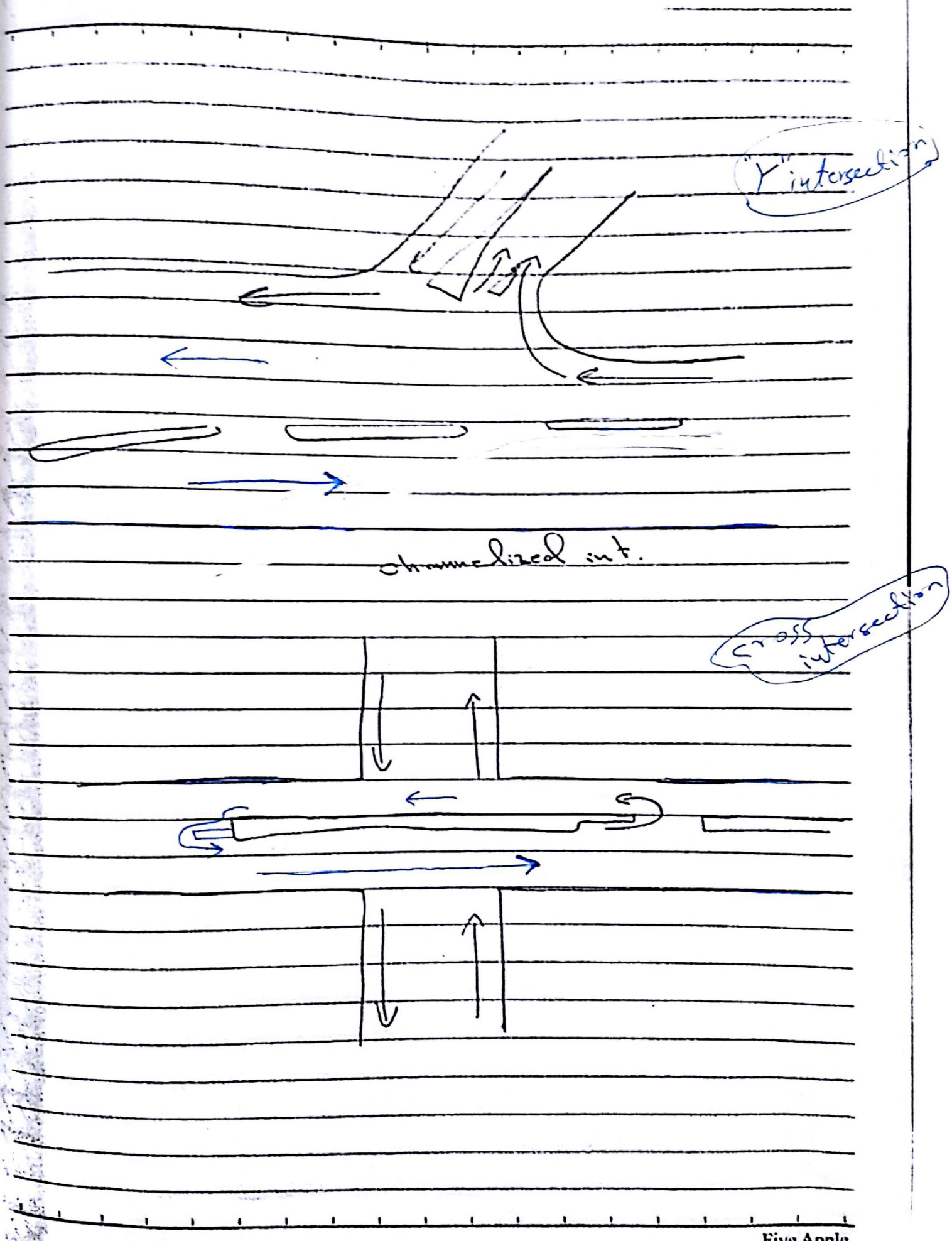
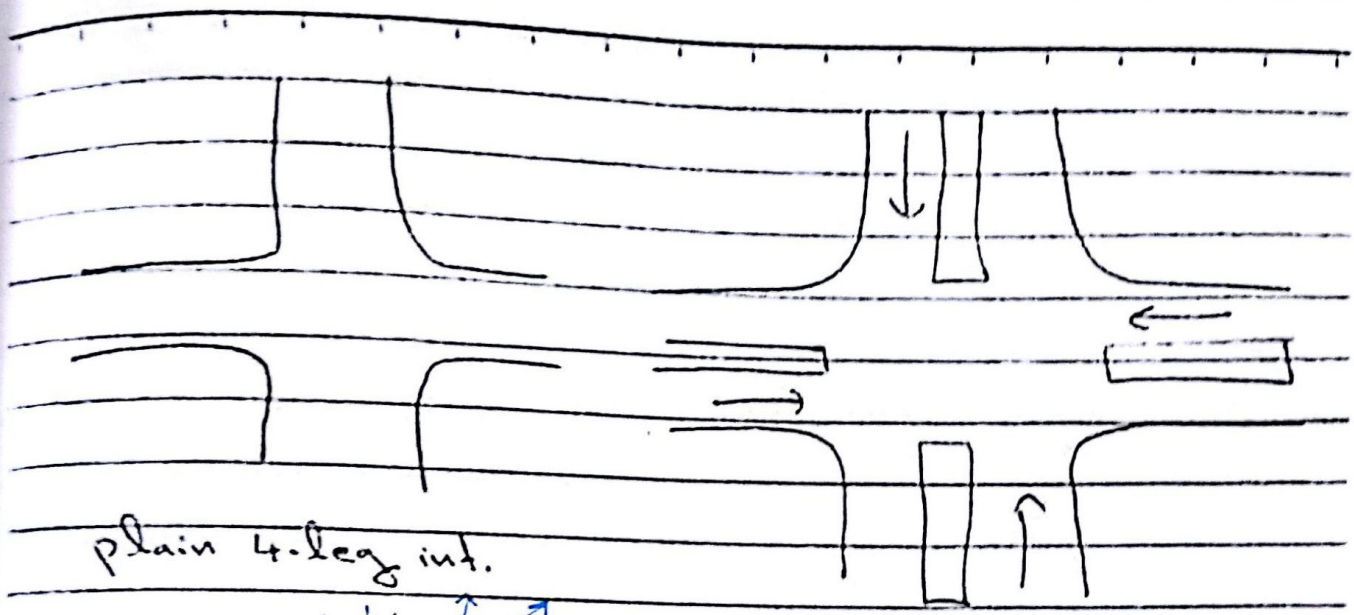
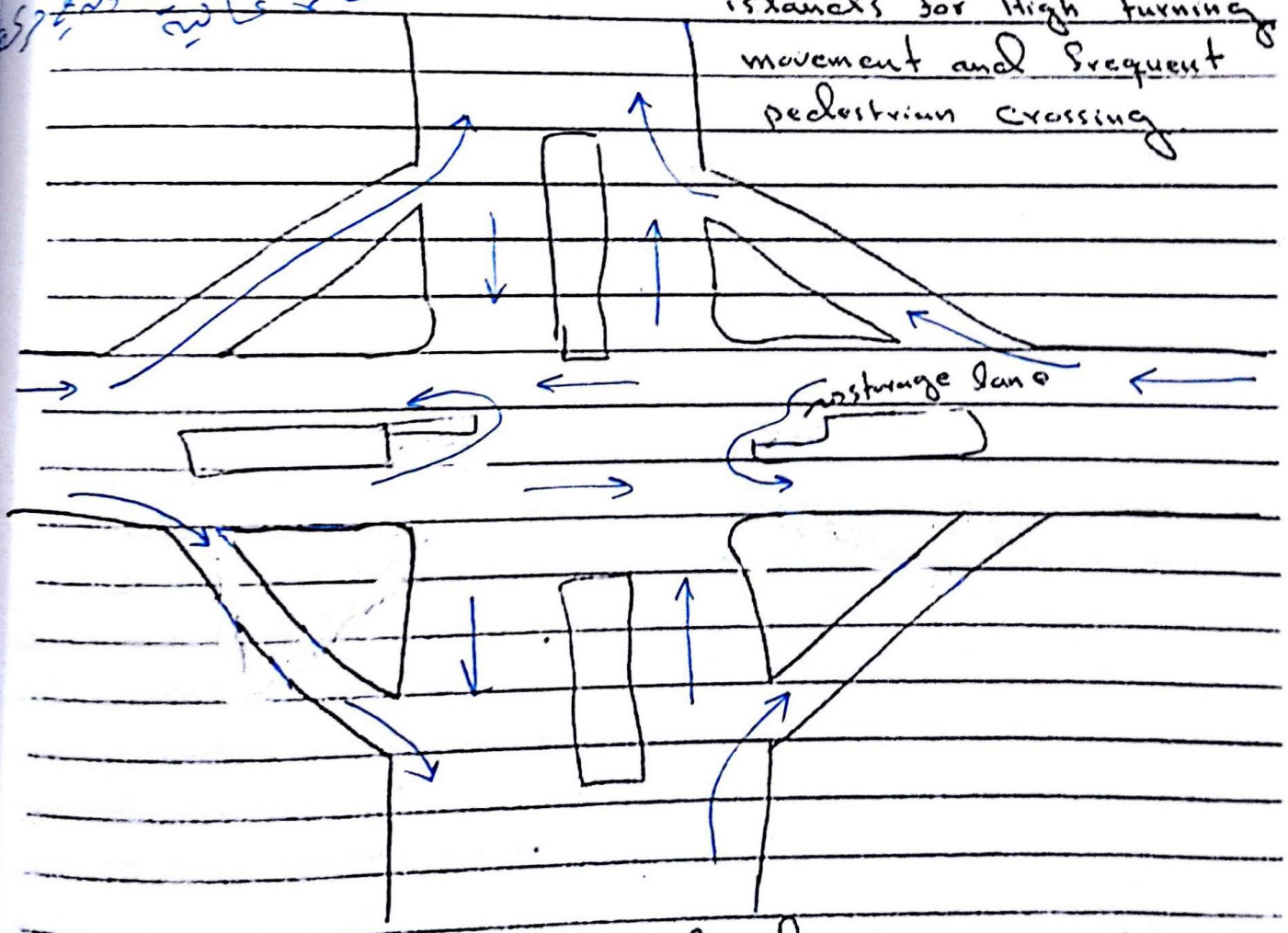


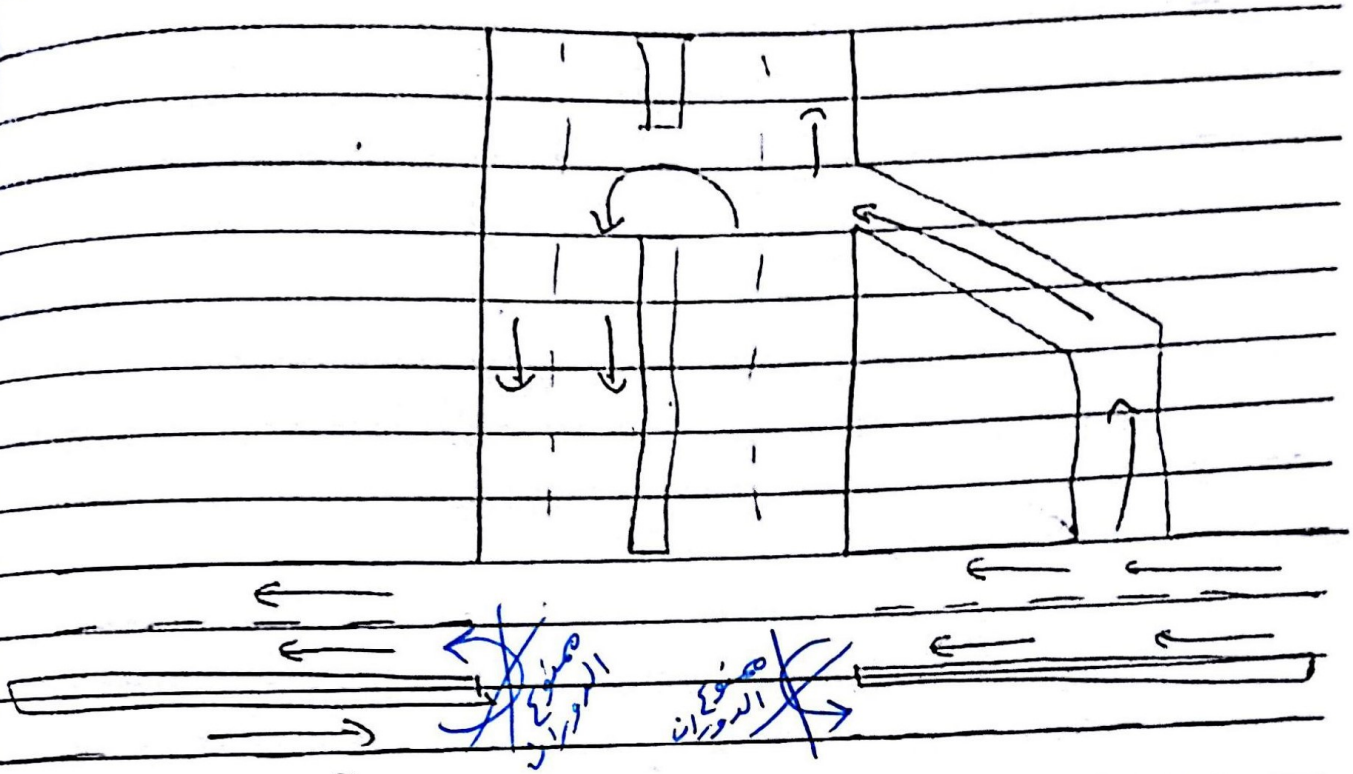


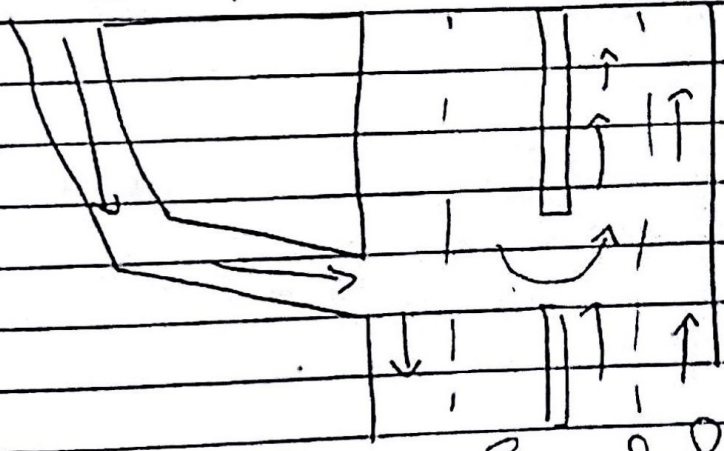
plain 4-leg int.

4-leg int. with divisonal islands for High turning movement and frequent pedestrian crossing



4- leg channelized int. high through and high turning volume (usually signalized)



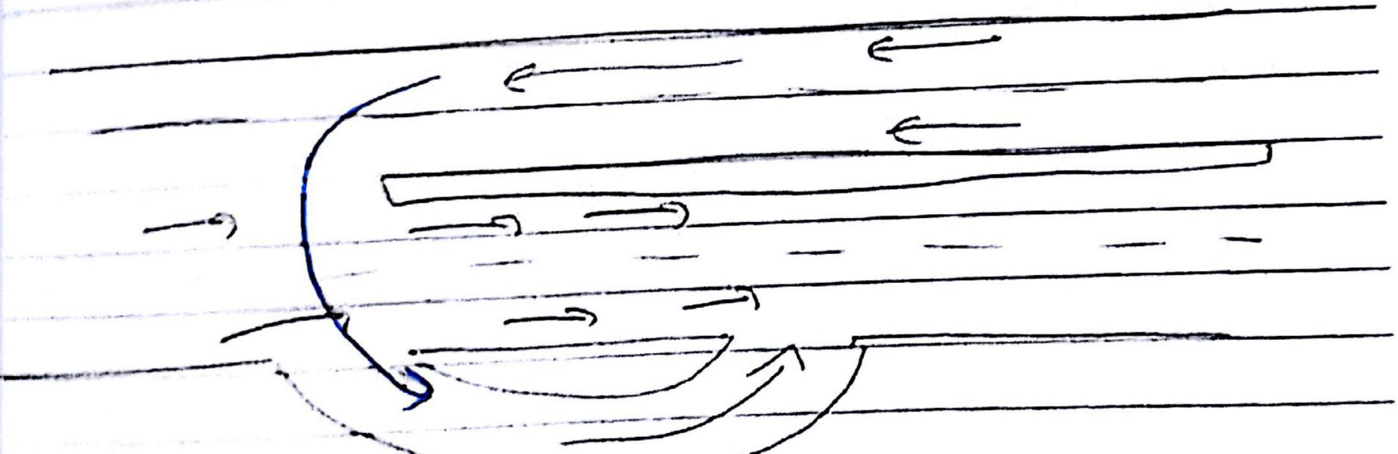


(بسبب وجود كثافة straight traffic)

Inn-handle design for left-turnings vehicle, also it is for high turnes that might needs signalization.

Left-turn handled on U-turn using right side (for long vehicle) (للشاحنات فقط)

or

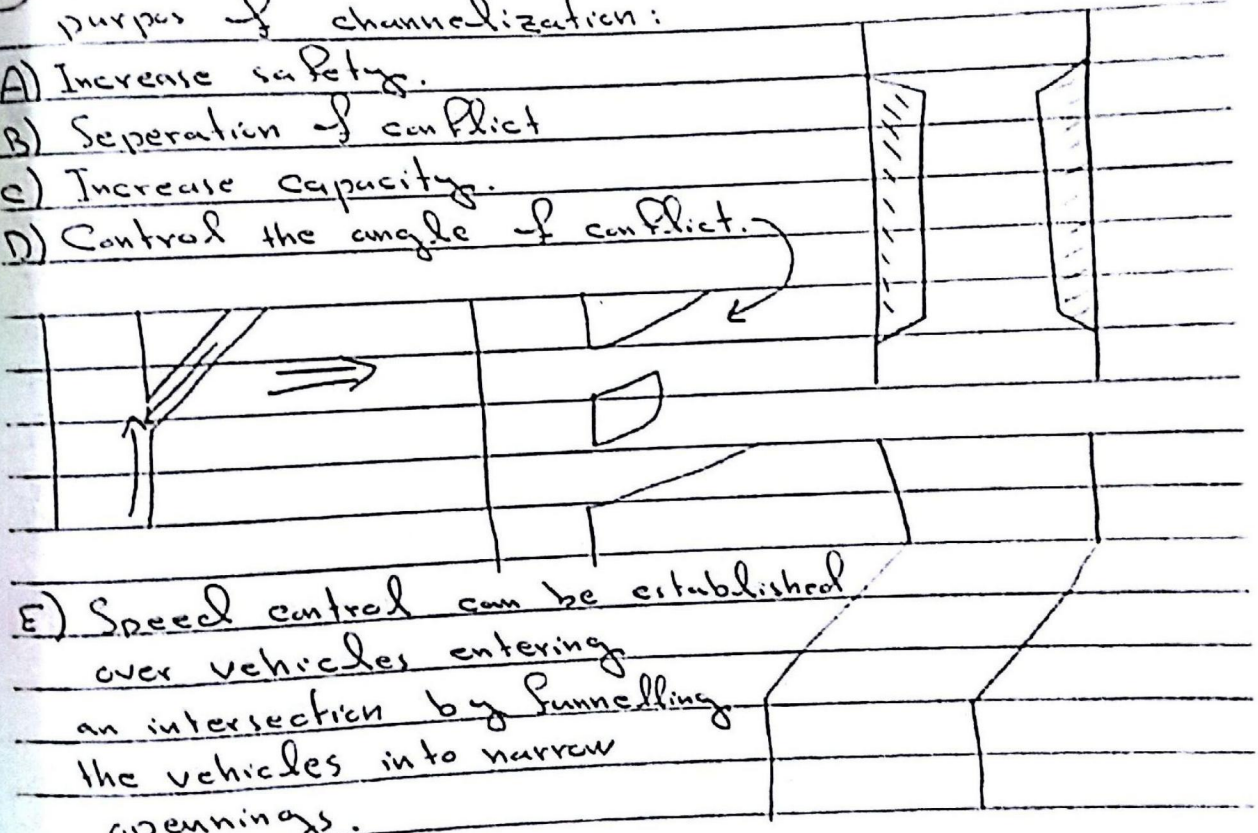


لأن الشاحنات بحاجة إلى عطف كبير لتعمل دوران

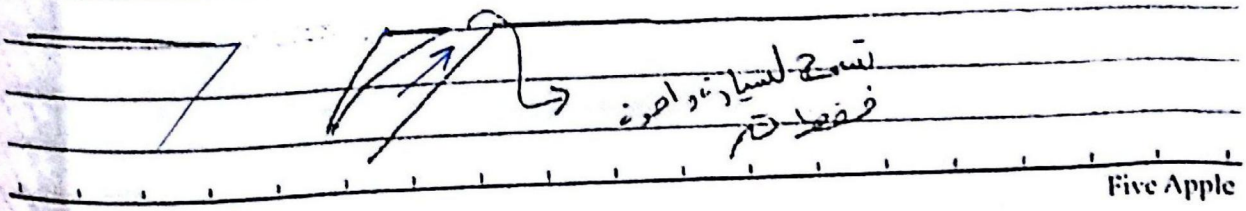
1) All paved or unchannelized int:-
The unchannelized int. are paved the whole area, and as such, there is no restriction to vehicle to use any part of the int. area. these intersections are the lowest order, same time the width of the pavement is widened at the intersections which is known as flared int.

2) Channelized intersections:
purpos of channelization:

A) Increase safety.
B) Seperation of conflict
C) Increase capacity.
D) Control the angle of conflict.



E) Speed control can be established over vehicles entering an intersection by funnelling the vehicles into narrow openings.



F) Prohibited turns may be presented.
G) Refuge may be provided for turning vehicles and pedestrian.

L25

* Round about:

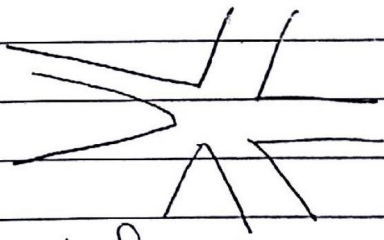
It is the alternative to the conventional at grade intersection; it consists of a centeroid island where travel is one-way counter clock-wise direction.

They are prefered to be used when:

1. There is equal traffic volume approaching from all direction.
2. when the design hourly volume approaching the int. does not exceed (3000 veh/h).

Following are the advantages of round about:

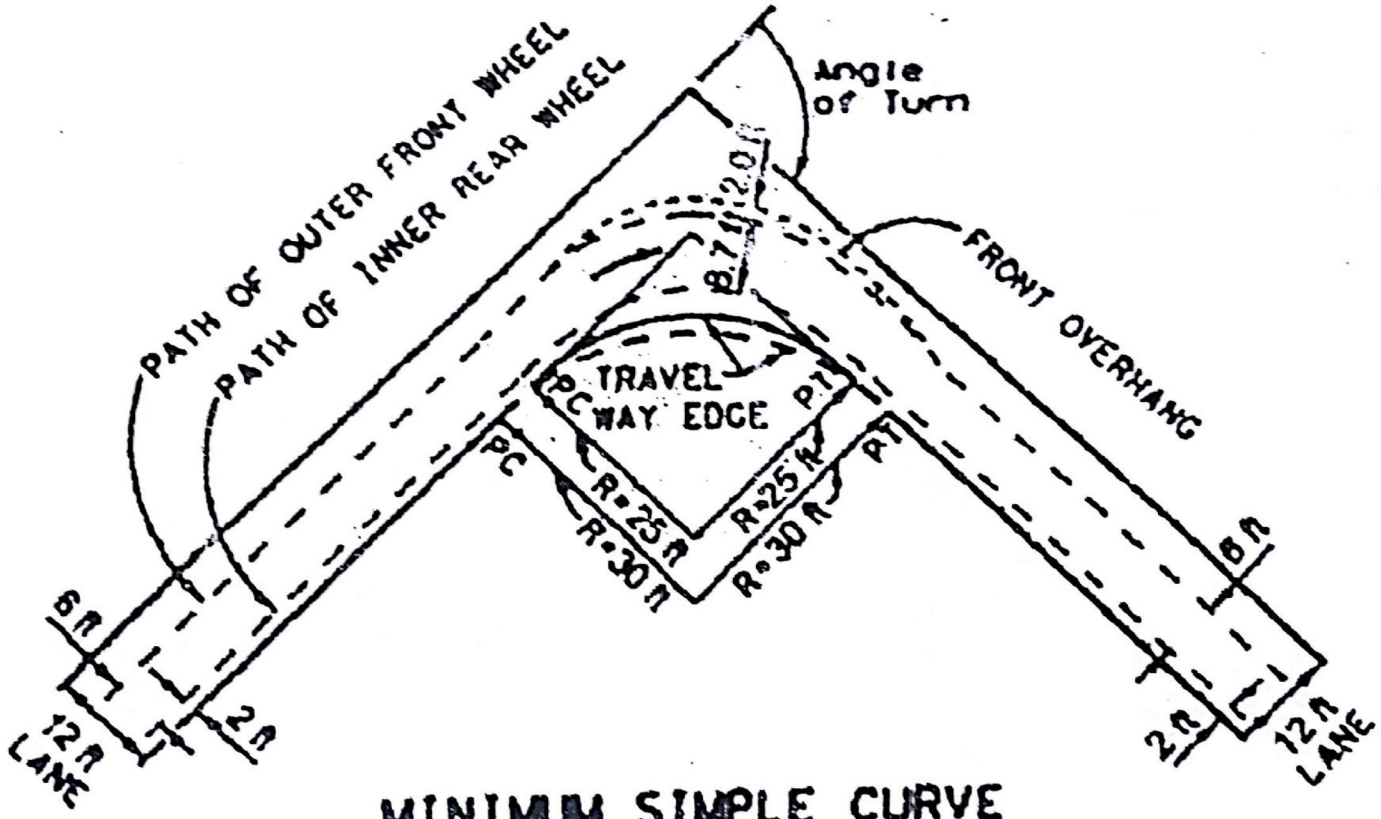
1. It provides simple solution to road junction, where more than four road meet
2. It regulate traffic and there is a continuous flow of traffic through the round about.
3. It is cheep to construct the seperated int.
4. It is self controlled, avoiding the neceessarity of traffic police or signal.



The Disadvantages of Round about :

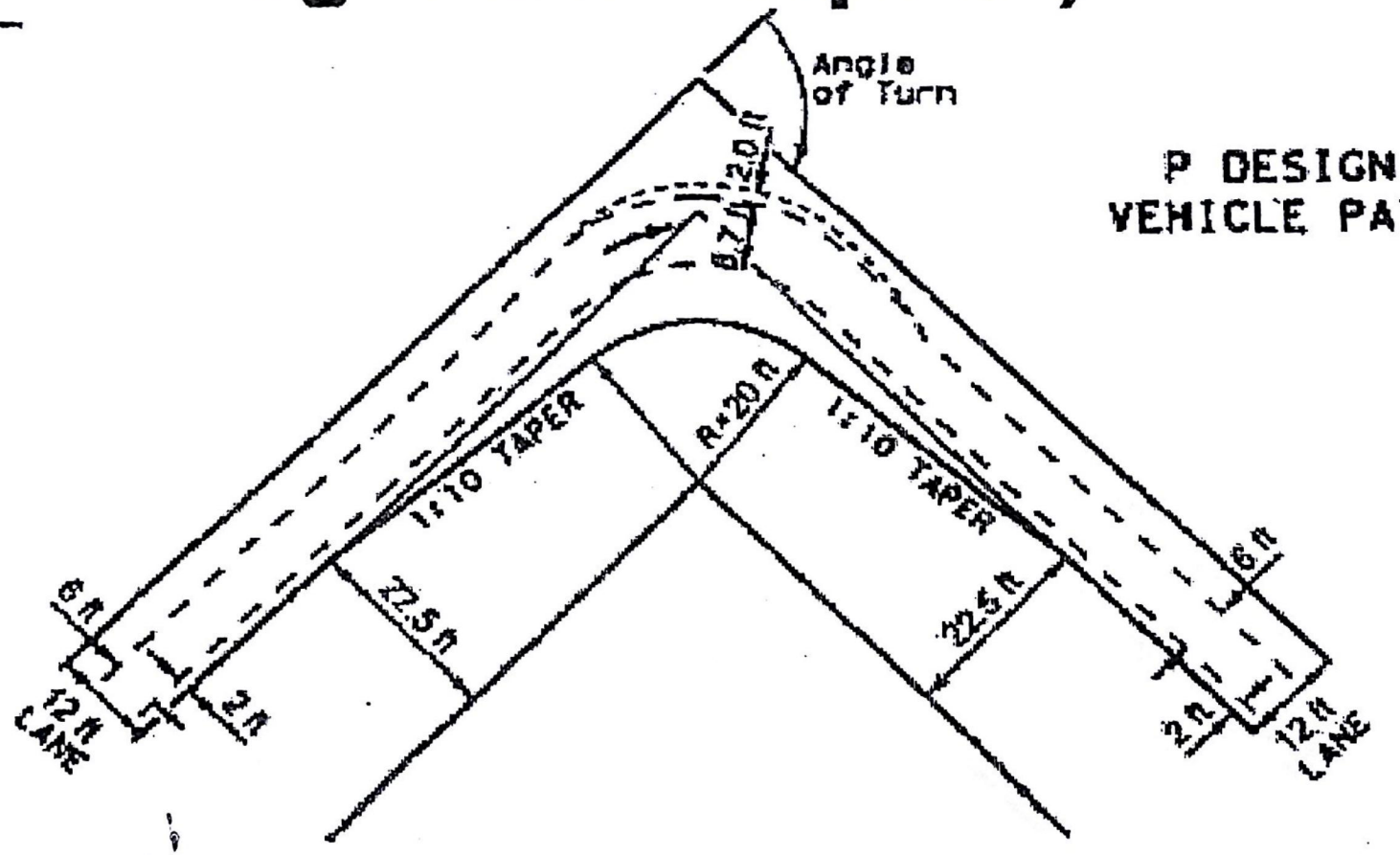
1. Difficult for pedestrians
2. It requires large area of flat land.
3. It is not function effectively if all approaches have similar traffic volume.
4. It is not suitable for high speed road
5. It is not possible to use it in congested area.

Simple Curve (passenger car template)



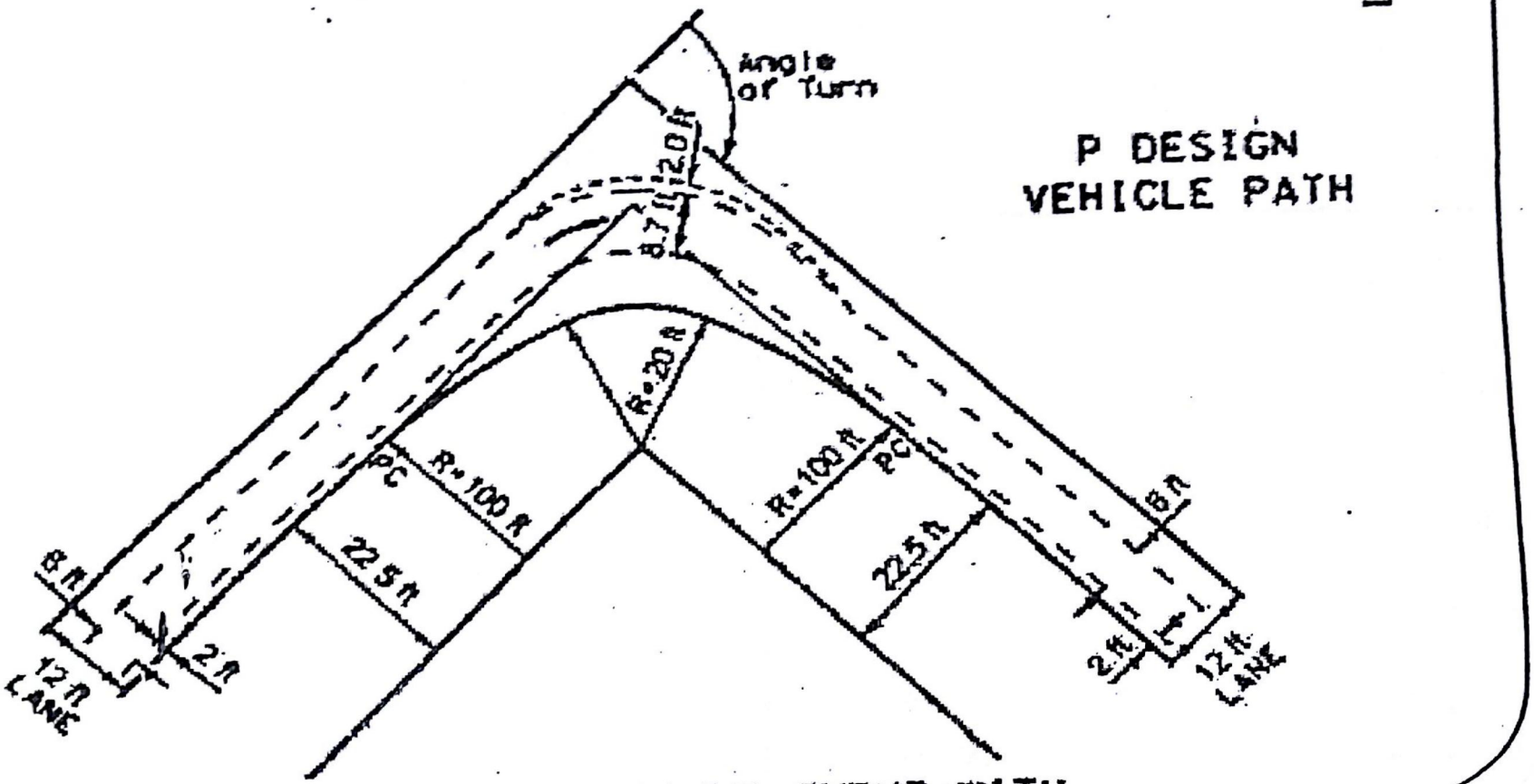
MINIMUM SIMPLE CURVE
25 ft OR 30 ft RADIUS
-A-

Simple Curve with Taper (passenger car template)



MINIMUM SIMPLE CURVE WITH TAPER 20 ft RADIUS, OFFSET 2.5 ft

Compound curves (passenger car template)

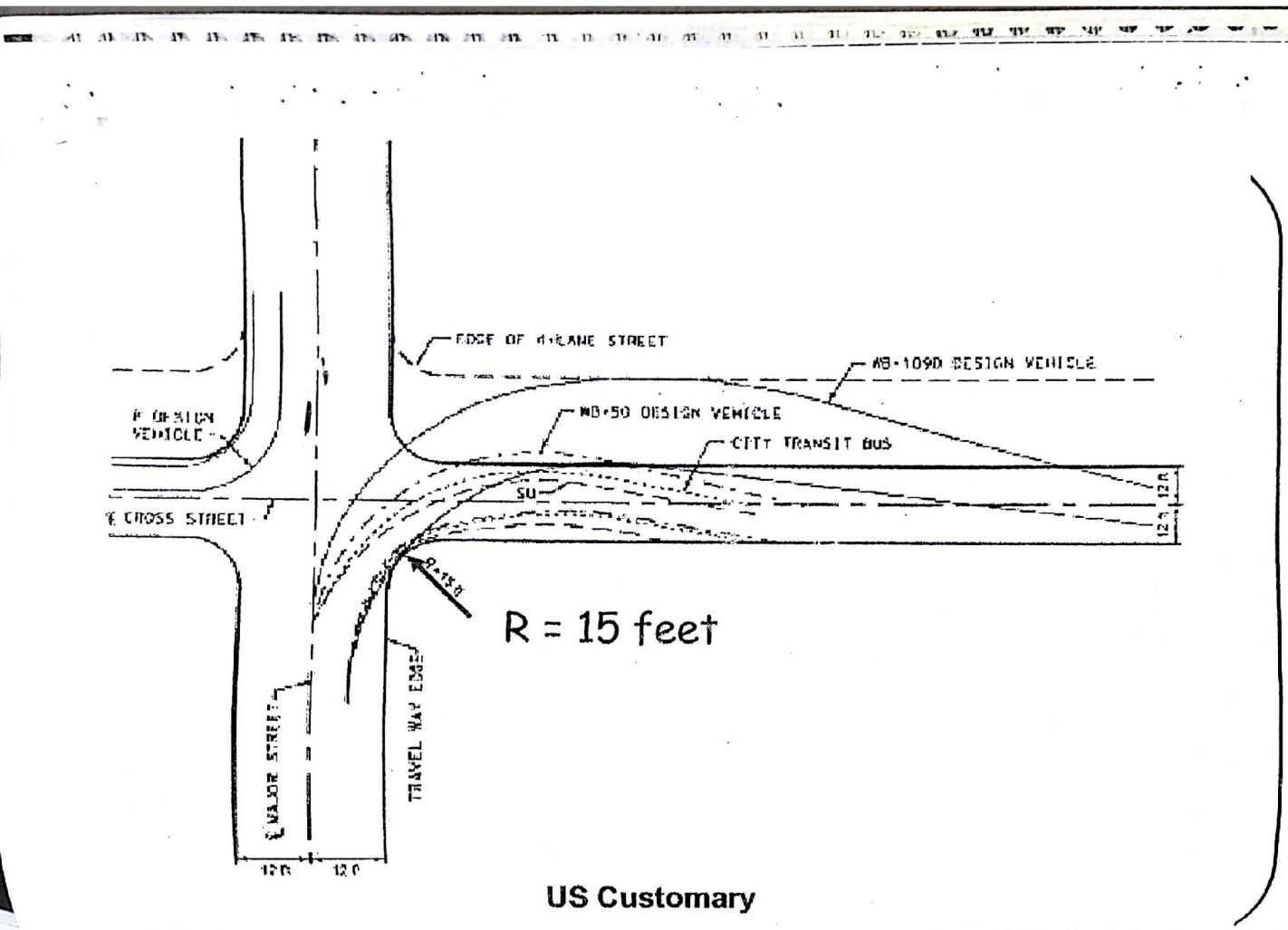


3 CENTERED COMPOUND CURVE WITH
100 ft - 20 ft - 100 ft RADII; OFFSET 2.5 ft

Metric						US Customary					
Angle of turn (degrees)	Design vehicle	Simple curve radius (m)	Simple curve radius with taper			Angle of turn (degrees)	Design vehicle	Simple curve radius (ft)	Simple curve radius with taper		
			Radius (m)	Offset (m)	Taper H:V				Radius (ft)	Offset (ft)	Taper H:V
75	P	11	8	0.6	10:1	75	P	35	25	2.0	10:1
	SU	17	14	0.6	10:1		SU	55	45	2.0	10:1
	WB-12	–	18	0.6	15:1		WB-40	–	60	2.0	15:1
	WB-15	–	20	1.0	15:1		WB-50	–	65	3.0	15:1
	WB-19	–	43	1.2	20:1		WB-62	–	145	4.0	20:1
	WB-20	–	43	1.3	20:1		WB-67	–	145	4.5	20:1
	WB-30T	–	26	1.0	15:1		WB-100T	–	85	3.0	15:1
	WB-33D	–	42	1.7	20:1		WB-109D	–	140	5.5	20:1
90	P	9	6	0.8	10:1	90	P	30	20	2.5	10:1
	SU	15	12	0.6	10:1		SU	50	40	2.0	10:1
	WB-12	–	14	1.2	10:1		WB-40	–	45	4.0	10:1
	WB-15	–	18	1.2	15:1		WB-50	–	60	4.0	15:1
	WB-19	–	36	1.3	30:1		WB-62	–	120	4.5	30:1
	WB-20	–	37	1.3	30:1		WB-67	–	125	4.5	30:1
	WB-30T	–	25	0.8	15:1		WB-100T	–	85	2.5	15:1
	WB-33D	–	35	0.9	15:1		WB-109D	–	115	2.9	15:1
105	P	–	6	0.8	–	105	P	–	20	2.5	–
	SU	–	11	1.0	–		SU	–	35	3.0	–
	WB-12	–	12	1.2	–		WB-40	–	40	4.0	–
	WB-15	–	17	1.2	15:1		WB-50	–	55	4.0	15:1
	WB-19	–	35	1.0	15:1		WB-62	–	115	3.0	15:1
	WB-20	–	35	1.0	15:1		WB-67	–	115	3.0	15:1
	WB-30T	–	22	1.0	15:1		WB-100T	–	75	3.0	15:1
	WB-33D	–	28	2.8	20:1		WB-109D	–	90	9.2	20:1

Metric						US Customary					
Angle of turn (degrees)	Design vehicle	3-centered compound Curve radii (m)	Symmetric offset (m)	3-centered compound Curve radii (m)	Asymmetric (m)	Angle of turn (degrees)	Design vehicle	3-centered compound Curve radii (ft)	Symmetric offset (ft)	3-centered compound Curve radii (ft)	Asymmetric (ft)
75	P	30-8-30	0.6	–	–	75	P	100-75-100	2.0	–	–
	SU	36-14-36	0.6	–	–		SU	120-45-120	2.0	–	–
	WB-12	36-14-36	1.5	36-14-60	0.6–2.0		WB-40	120-45-120	5.0	120-45-195	2.0–6.5
	WB-15	45-15-45	2.0	45-15-69	0.6–3.0		WB-50	150-50-150	6.5	150-50-225	2.0–10.0
	WB-19	134-23-134	4.5	43-30-165	1.5–3.6		WB-62	440-75-440	15.0	140-100-540	5.0–12.0
	WB-20	128-23-128	3.0	61-24-183	0.3–3.0		WB-67	420-75-420	10.0	200-80-600	1.0–10.0
	WB-30T	76-24-76	1.4	30-24-91	0.5–1.5		WB-100T	250-80-250	4.5	100-80-300	1.5–5.0
	WB-33D	213-38-213	2.0	46-34-168	0.5–3.5		WB-109D	700-125-700	6.5	150-110-550	1.5-11.5
90	P	30-6-30	0.8	–	–	90	P	100-20-100	2.5	–	–
	SU	36-12-36	0.6	–	–		SU	120-40-120	2.0	–	–
	WB-12	36-12-36	1.5	36-12-60	0.6–2.0		WB-40	120-40-120	5.0	120-40-200	2.0–6.5
	WB-15	55-18-55	2.0	36-12-60	0.6–3.0		WB-50	180-60-180	6.5	120-40-200	2.0–10.0
	WB-19	120-21-120	3.0	48-21-110	2.0–3.0		WB-62	400-70-400	10.0	160-70-360	6.0–10.0
	WB-20	134-20-134	3.0	61-21-183	0.3–3.4		WB-67	440-65-440	10.0	200-70-600	1.0–11.0
	WB-30T	76-21-76	1.4	61-21-91	0.3–1.5		WB-100T	250-70-250	4.5	200-70-300	1.0–5.0
	WB-33D	213-34-213	2.0	30-29-168	0.6–3.5		WB-109D	700-110-700	6.5	100-95-550	2.0–11.5
105	P	30-6-30	0.8	–	–	105	P	100-20-100	2.5	–	–
	SU	30-11-30	1.0	–	–		SU	100-35-100	3.0	–	–
	WB-12	30-11-30	1.5	30-17-60	0.6–2.5		WB-40	100-35-100	5.0	100-55-200	2.0–8.0
	WB-15	55-14-55	2.5	45-12-64	0.6–3.0		WB-50	180-45-180	8.0	150-40-210	2.0–10.0
	WB-19	160-15-160	4.5	110-23-180	1.2–3.2		WB-62	520-50-520	15.0	360-75-600	4.0–10.5
	WB-20	152-15-152	4.0	61-20-183	0.3–3.4		WB-67	500-50-500	13.0	200-65-600	1.0–11.0
	WB-30T	76-18-76	1.5	30-18-91	0.5–1.8		WB-100T	250-60-250	5.0	100-60-300	1.5–6.0
	WB-33D	213-29-213	2.4	46-24-152	0.9–4.6		WB-109D	700-95-700	8.0	150-80-500	3.0–15.0

Exhibit 9-20. Edge of Traveled Way for Turns at Intersections *(Continued)*



US Customary

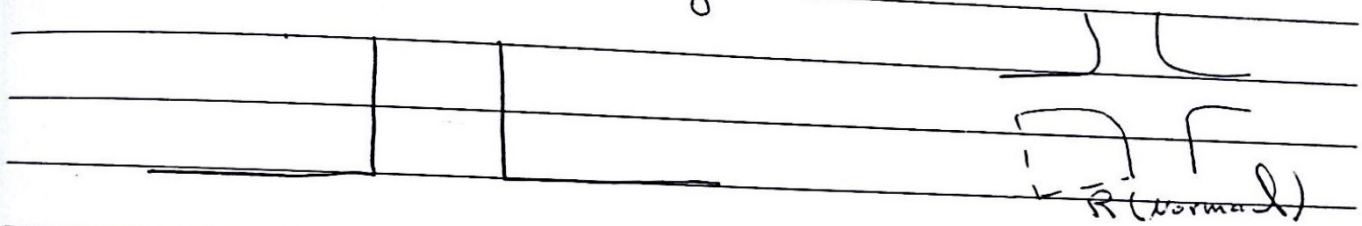
Exhibit 9-29. Effect of Curb Radii on Right Turning Paths of *Various Design Vehicles*

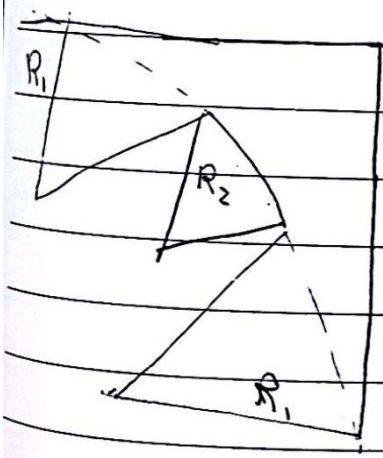
⊛ Intersection Design:

where traffic consist of passengers vehicles arc of circles with radius of (4.5m - 7.5m) is sufficient.

whenever feasible corner radius of 7.5 to 9 m should be provided for Minor & Major roads on new construction. Table (9.19) & (9.20) give recomended pavement design of int.

Three-Centered Compound curves are recomended for sharp turns or for large vehicle.





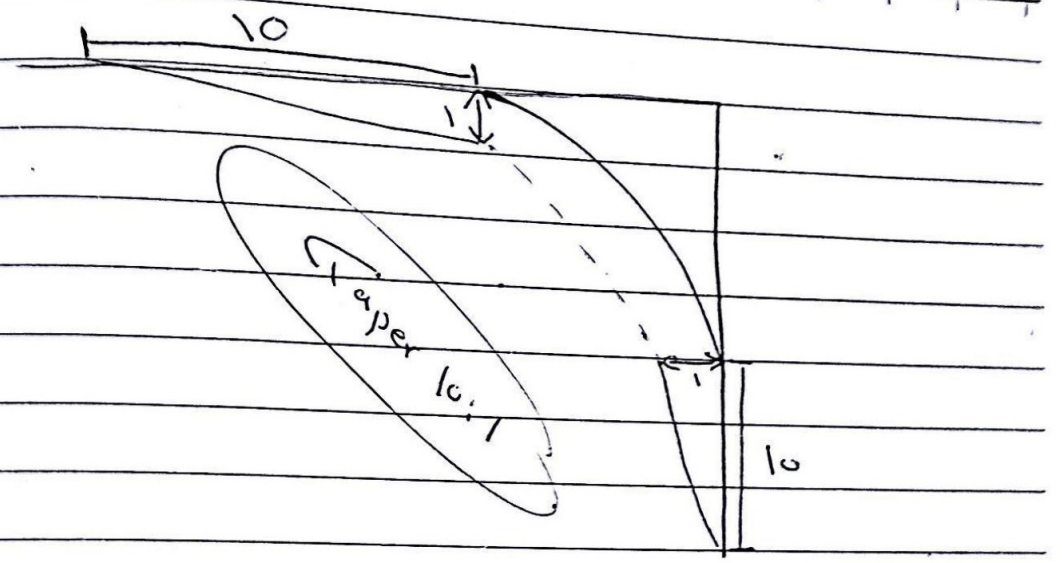
Example Question:

A tall building is located 45ft from the centreline of the right lane of a local road. (b. in the figure)

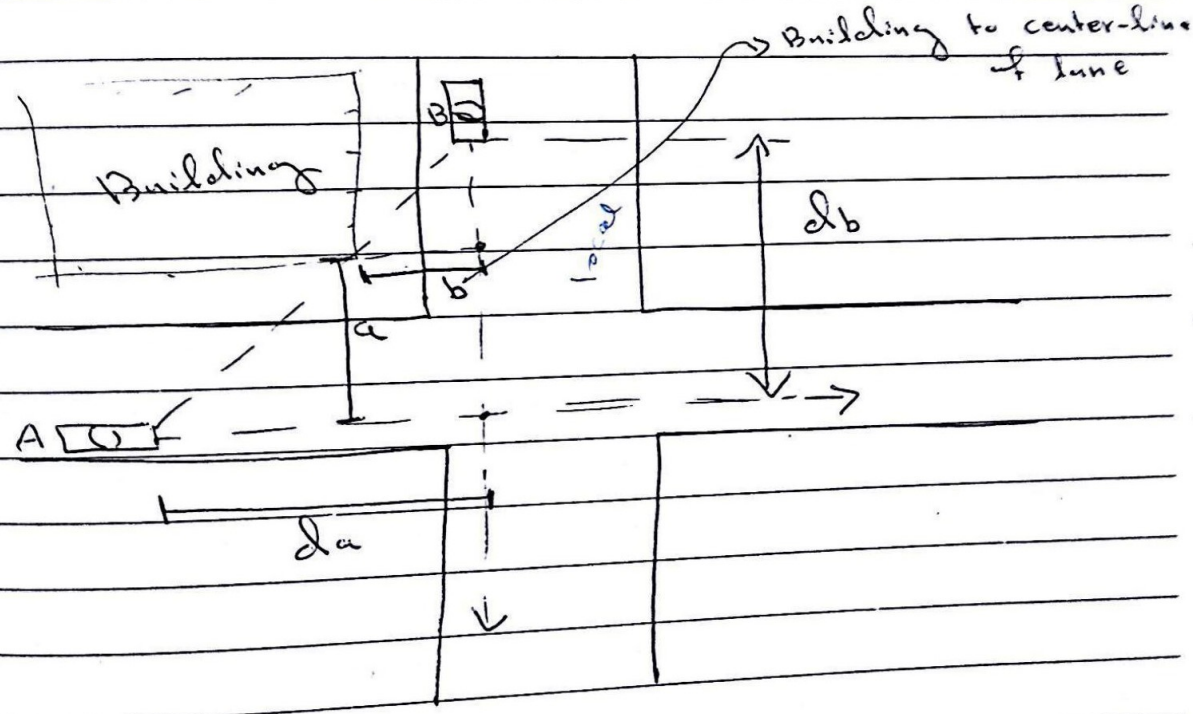
and 65ft from the centreline of the right lane of an intersecting road. . (a. in the figure).

If the maximum speed limit on the intersecting road is 35mph.

What should the speed limit be on the local road to be such that the minimum sight distance is provided to allow the drivers of approaching vehicles to avoid imminent collision by adjusting their speed?



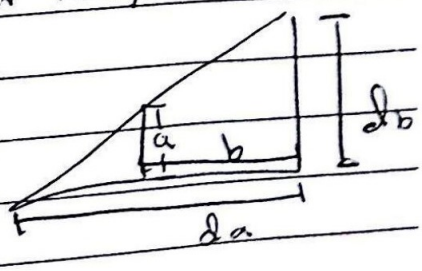
Sight Distance at intersection:



SSD = 1.47 $v t_r$ (v in mile per hour) $t_r = 3$ sec

= 0.277 $v t_r$ (v in Km per hour)

$$\frac{d_b}{d_a} = \frac{a}{d_b - b}$$



Example:

$b = 45$ ft , $a = 65$ ft , 35 mph $= v$

$d_a = SSD = 1.47 v t_r = 1.47 * 35 * 3 = 155$ ft

$d_b \Rightarrow \dfrac{d_b}{155} = \dfrac{65}{155 - 45}$ $\boxed{d_b = 91.6 \text{ ft}}$

$\Rightarrow 91.6 = 1.47 v * 3$

$v = 20.8$ mph $\rightsquigarrow$ take $v = 20$ mph

* Grade Seperation is the arrangment of taking one road over or under another by means of abridge; it is also known as a fly-over.

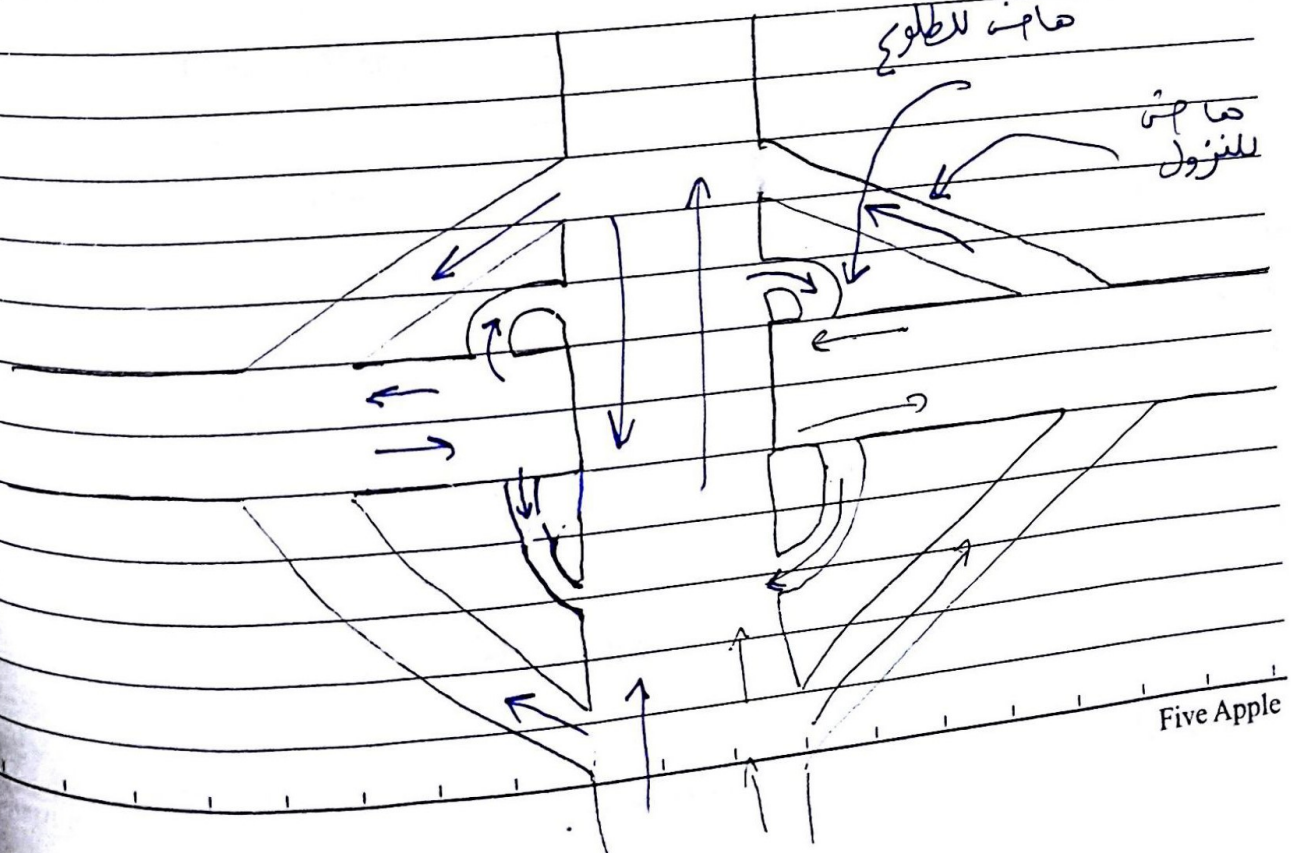
The grade seperation and interchanges may be warrented if:

1. It is decided to have limited ~~acces~~ acces cross road
2. To increase safety
3. To eliminate bottle neck's.
4. If the topography is such that the other types of design are not feasible.
5. If there was high traffic volume.

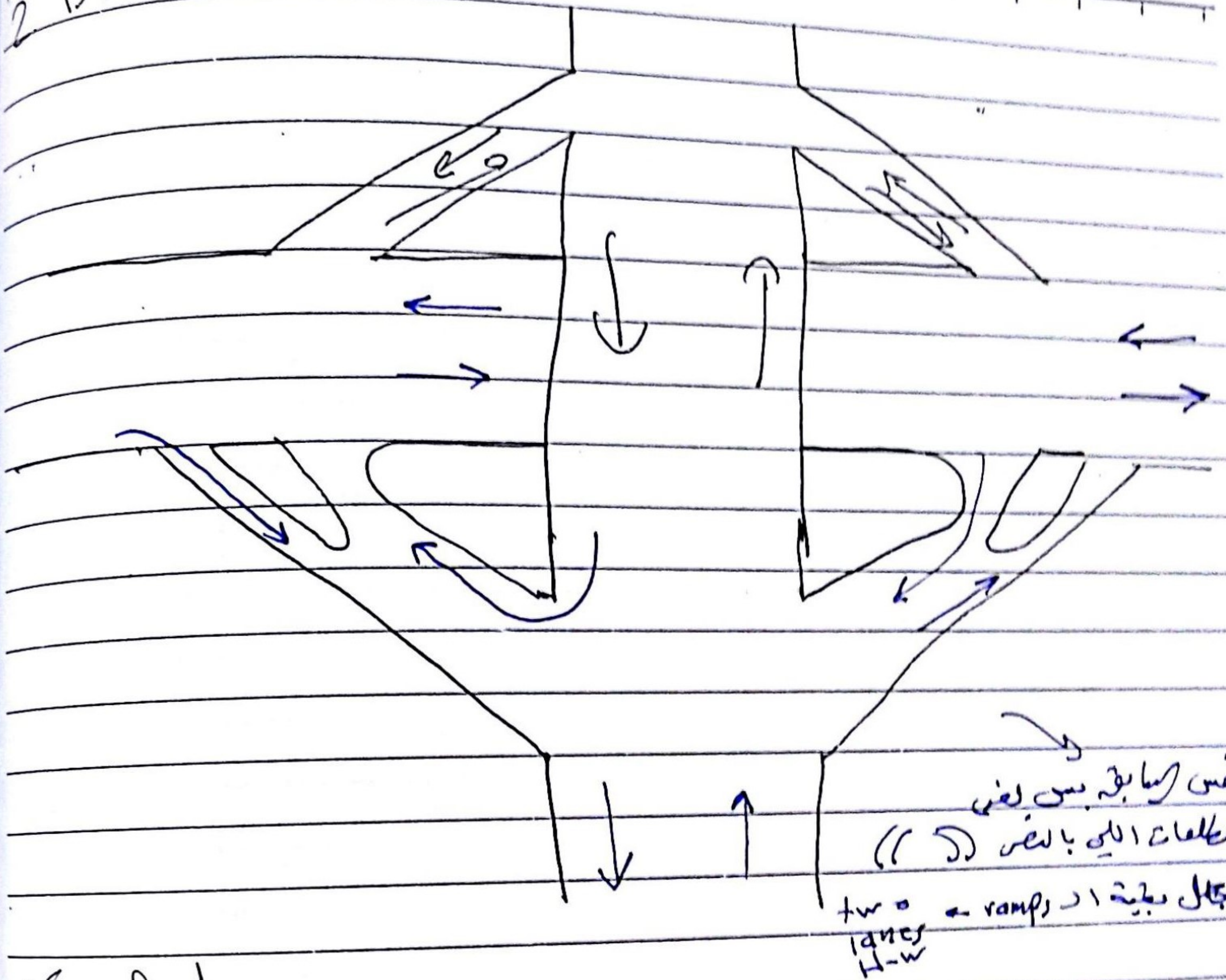
An interchange is grade seperation in which vehicle moving is one direction

The interchange maybe of various types:

1. Clover Leaf:

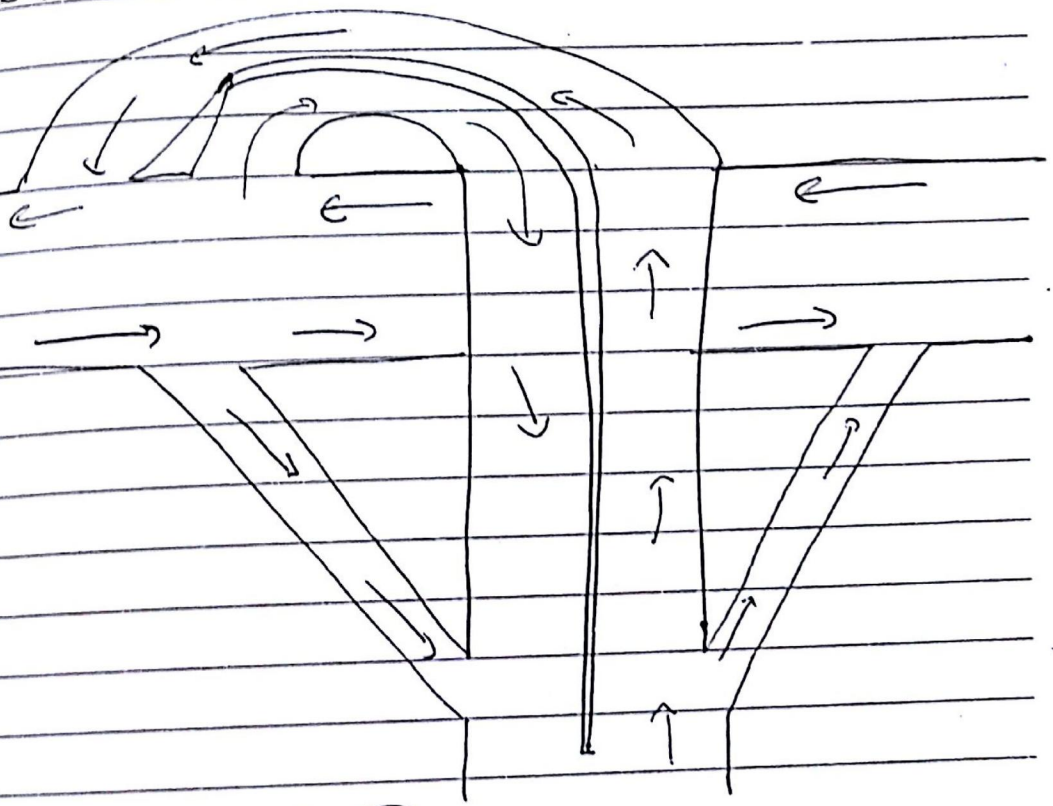


2 Diamond :



* Simplest
* Most Common
* least costly type of interchange
* Small Row (Right of Way)

③ Trumpet:
used of T-Junction
* Least Costly
* little Row



④ All Directional: Google images
* the name implies that travel is directional towards your distination.
* multiple layers.
* very high speed.
* very high traffic volume
* free-way to free-way connection

(*) Drainage of city streets:

The surface drainage of city streets is different from rural Hwys.

Open drains can't be used, because they are unsightly (منظر غير لائق), occupy more space, and serve as a source of danger, to the traffic there for underground drains &. sewers are used.

The surface water drainage system in a city composed of the following:

[1] Pavement Crown
[2] Storm Drains
[3] Inlet, catch Basin & manholes

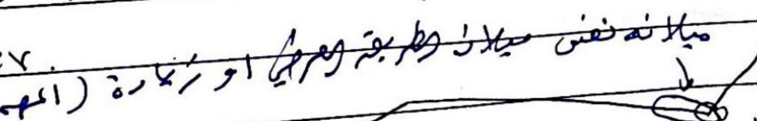
مغلق من فوق

مفتوح من فوق

The crown should be as small as possible for appearance and safety.

The longitudinal grade of the gutter must be sufficient to facilitate repaid removal of the water.

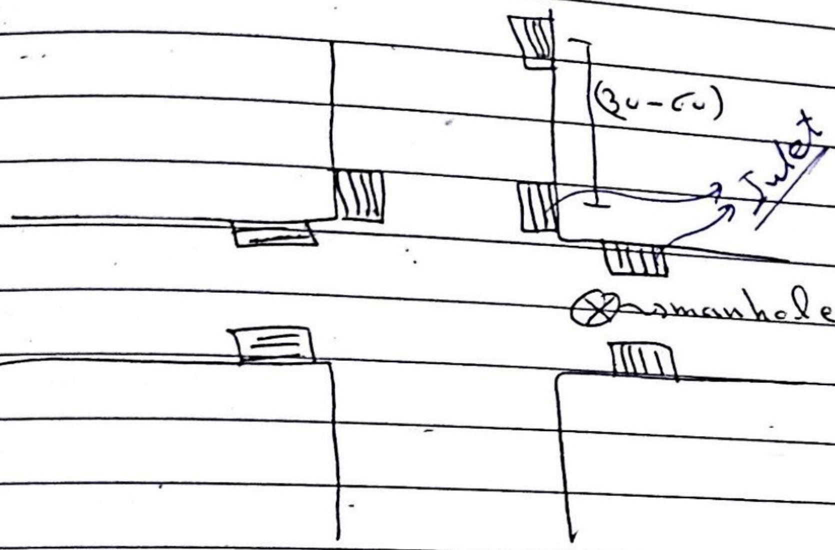
~~ميلانه نفس ميلان الطريق عرضيا~~ او زيادة (المهم يكون كافي لتجميع الامطار).



At sags where water is collected an inlet must be provided.

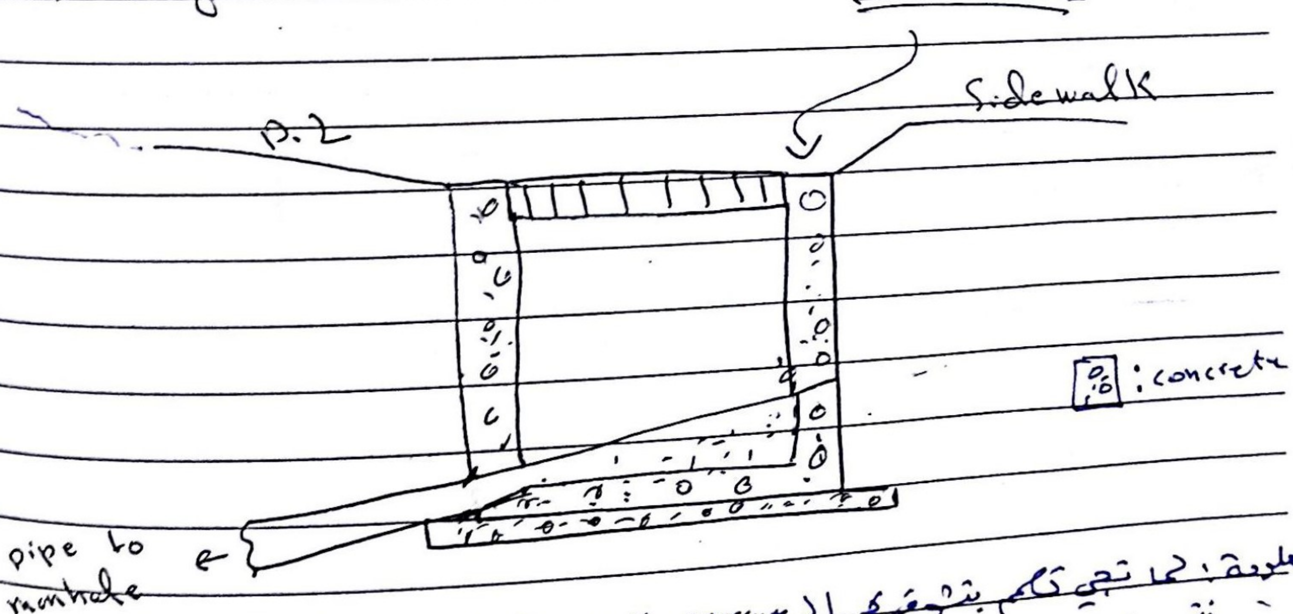
زي الانفاق وبيكون في تصريف هناك.

<u>Inlets</u>: They are usually provided at intersection:



- inlets are located by the sides of roads (30-60)m connected by manholes
- the purpose of inlet is to collect storm water in short period and there is no flooding.

- the inlet is simply a concrete box, it may have openning in vertical direction or <u>horizantal</u> direction

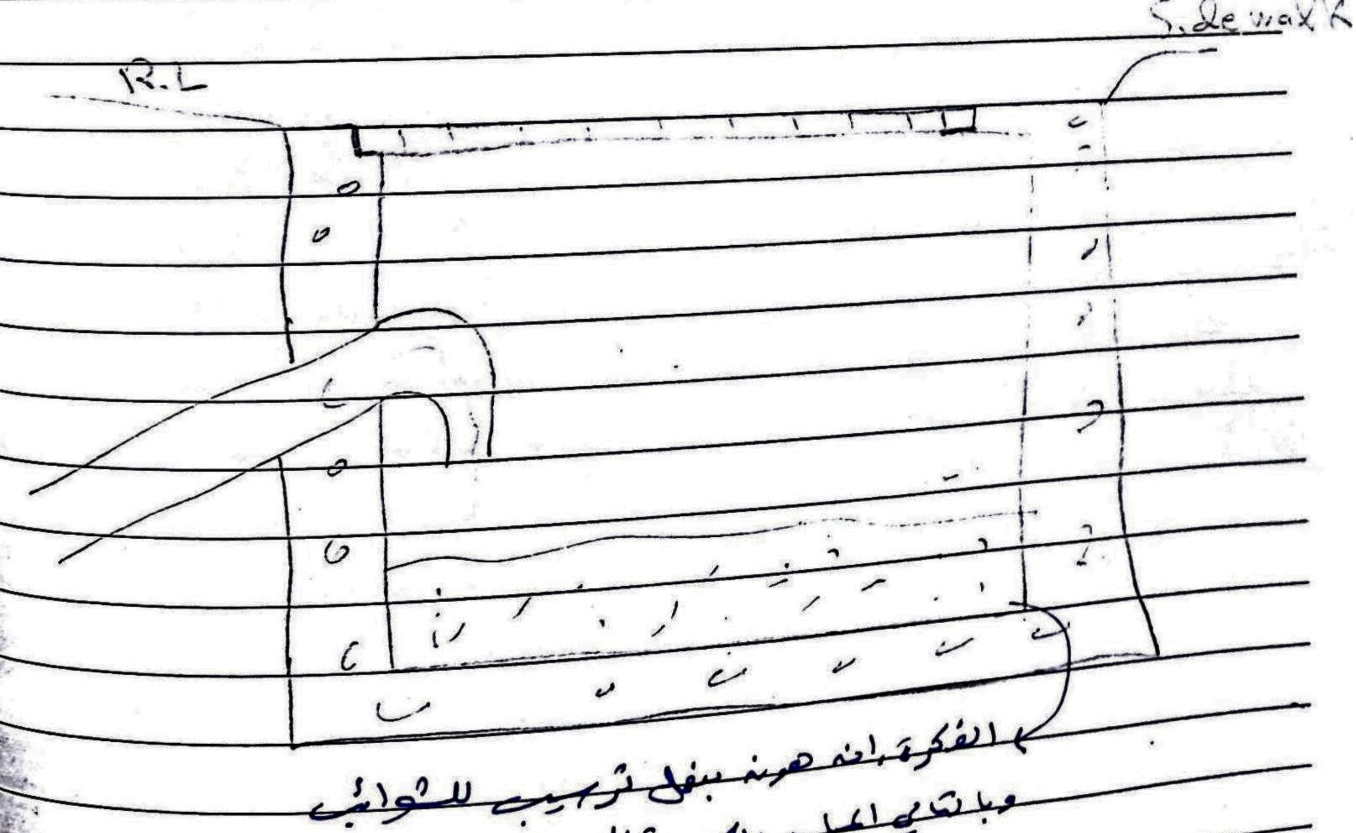


ملاحظة: لما نجي نتكلم بنتوقع كم الـ pressure للماء (ρgh) وكم قوة رح
نتحدد كم عرضه وسماكته اللازم لمقاومة ذلك لأنه لو ما بتحمل رح يصير
فيها cracks.

Inlets have only an outlet pipe (circular) placed at the bottom of the inlet, inlets are subjected to clogging the objects that causes troubles (clogging) of the opening are sticks wast papers, leaves, debries, so ~~that~~ they must be cleaned frequently.

* Catch Basin : They are similar to inlet in their function & design ; the difference in the outlet pipe is placed at same distance above the bottom of the chambes.

the purpose of the catch basin is that the debries flushed from the street is tranned in the bottom of the catch basin so that it doesn't enter in the storm sewer.



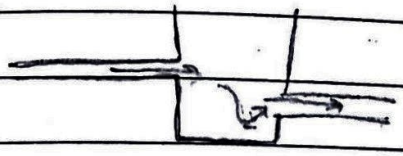
الفكرة انه هون بيصير ترسيب للشوائب وبالتالي المياه اللي بتطلع من ال pipe حتكون صافية وهذا فرقه عن ال inlet

Manholes:

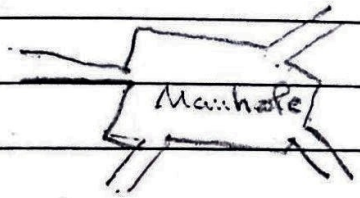
Storm sewer systems are subjected to partial or complete clogging and facilities must be provided for cleaning.

Manholes are placed at points where:

1) Sewers change direction
2) when the sewers change grade.

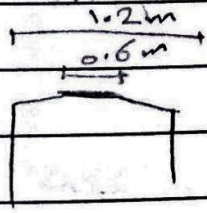


3) Where there are junction (intersection)



4) At intermediet points (90-150m)

The opening should be large enough to permit a man to enter the chambes to clean it, diameter (1.2m), manhole covers are cast iron circular shape (0.6m d)



(*) Drainage and drainage structure:

The structure ~~which~~ which provide drainage are:

1. Pavement Crown.
2. Shoulders & Side slope.
3. longitudinal ditches.
4. Bridges and culverts.
5. Inlets and catch basins, Mlt.

(*) Side slope and side ~~ditch~~ ditches:

Side ditches are provided along the hwy in rural areas in cut section.
they are V-shape or flat bottomed open channels.
avoide deep & narrow ditches → hazardous
Grade for the ditch should be same as the road centre line.

(*) Culvert, Bridges:

The difference between culvert and bridges is in the span length.
span < 20 ft is called culvert.
span > 20 ft is called Bridges

- Culverts are found in three locations:
1. at the bottom of depressions (انخفاضات) (مثل الـ sag)
2. where natural streem intersect the road-way (عند الأنهار/السيول)
3. At locations required for passing surface drainage carried in side ditch →

الـ ditch لما تقطعها مارقة فيها ميه و تتقاطع مع الطريق بالآخر لازم نعمل culvert لنصل للـ...

Shapes: Box, Circular, Arch, ellipse

(*) Culverts are installed at right angle or on a skew. // skew angle (يفضل تكون °90 وبالتالي أرخص)

Culvert if possible should cross at right angle to reduce the cost العبارة القائمة بتكون أقصر من المائلة فبالتالي بتكون أرخص

The grade of the culvert should conform to the existing grade of the stream.

If grade is reduced then the velocity may be reduced, then will cause sediments carried in the water deposited in the culvert
→ capacity will be reduced

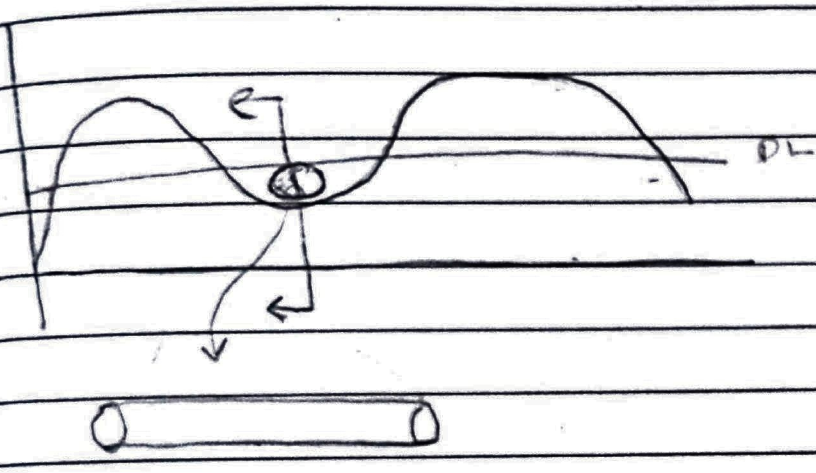
increasing slope will increase velocity, hence it causes erosion, protective measures is needed at the outlet.

2% slope for culvert in the average it will keep the culvert clean.
while at the same time the water speed is kept at reasonable level.
speed of water should be between (1.5 – 3) m/s

Hydraulic design of culverts :-

The design involves the following procedure:

① obtain all site data and plot road-way cross-section at the culverts site, including the profile of the channel stream



منسوب مدخل

② Establish the culvert invert level elevation of the inlet and culvert and outlet ... the culvert length and slope

③ Determine the allowable head water depth of the probable depth of tail water during the design flood

④ Select the type and size of culvert and design features

⑤ Examine the need for energy dissipators and where is needed (تشتت الطاقة مشان ما تنجرف التربة)
(Provide protective devices to prevent errosion)

(*) Design of surface drainage system:

The design is divided into 3-phases.

(1) An estimate of the quantity of water.

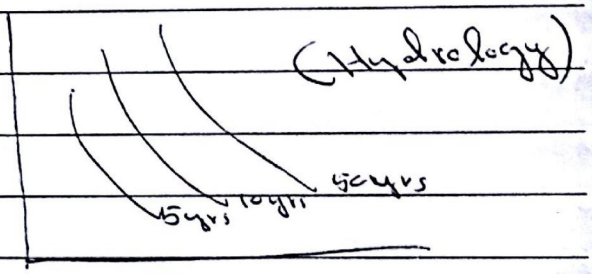
(2) The hydraulic design of each element of the system.

(3) Comparision of alternative system

(*) Estimation of the quantity of water

a. perform statistical analysis on the recorded stream flow to provide an estimated peak design flow for a given design (return-period)

(*) Rainfall Intensity (i)



(*) surface runoff:

The design of drainage must be provided for all rainfall does not infiltrate the soil.

The infiltration depends on:

(1) Type of soil (coarse absorb more than slow)

(2) Soil Covers (grasses reduce the infiltration)

(3) Moisture content of the soil.

(4) Tempreture

(5) Slope of surface

Type of drainage area	Coefficient of runoff (C)
Cement, pavement asphalt surface	(0.75) – 0.(95) → More safe → cheapest
Gravel Surface	0.25 – 0.6
Sandy soil, Cultivated	0.15 – 0.3
Clay soil cultivated	0.3 – 0.75
Urban buisness district	0.6 – 0.8
Urban resedential	0.5 – 0.7
Rural "	0.35 – 0.6

لو اعطاك clay ٪٥٠ و ٪٥٠ ...

$$\frac{\left(C_2 \times \frac{A}{2} + C_1 \times \frac{A}{2}\right)}{\Sigma A}$$

$\frac{A}{2} \rightarrow 0.5 * A$

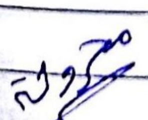
use weighted avg

cheapest ... restricted design

الاقل ← الاكبر ←

Avg Runoff water speed over surface conditions, for time concentration (m/s)

Surface Conditions	Slope 0 - 3	4 - 7	8 - 10	11 - 15
wood land	0.15	0.3	0.45	0.5
Pavement	1.5	3.65	4.7	5.5
Soil Cultivated	0.25	0.45	0.65	0.8



* The Rotational Method :-

The rotational method is used to estimate runoff from drainage area :

$Q = CIA$

- m^3/s
- mm/h
- hectare

Q = Run off (m^3/s)

C = Coeff. (The ratio of runoff to rainfall)

I = Intensity of rainfall

A = Drainage area in hectare

1 Hectare = 10 Donums = 10,000 m^2

A_1 C_1	A_2 C_2
A_3 C_3	A_4 C_4

$$\Sigma A = A_1 + A_2 + A_3 + A_4$$

$$C = \frac{C_1A_1 + C_2A_2 + C_3A_3 + C_4A_4}{\Sigma A}$$

* Design of culverts and Ditches:

$$Q = VA$$

$$V = \frac{R^{3/2} + S^{1/2}}{n} + \text{- - -}$$

Manning

Example: An Engineer plans to install a culvert under a collector type hwy to reduce flooding [illegible] area. The drainage area is 9 hectares of soil cultivated in a rural residential area. Water in the drainage area flows on approximate 5% slope for 1215m before reaching the culvert. Estimate the discharge that can be expected at culvert. Use design period = 10 years

Sol:

From table → speed = 0.45 m/s

$$T = \frac{1215\ m}{0.45\ m/s} = 2700\ sec = 45\ min$$

$Q = CIA$

$C = 0.6$ (From the table)

$I = 47\ mm/h$ (From the chart)

$$Q = \frac{0.6 * 47 * 9}{360} = 0.706\ m^3/s$$

$$0.6 \times \left(47 \times \frac{10^{-3}}{3600}\right) \cdot \left(9 \times 10{,}000\right)$$

$$= \frac{0.6 \times 47 \times 9}{360} = 0.706\ m^3/s$$

* If the water flows at (1.5 m/s) in the pipe find the diameter of the pipe ?

Sol:

$Q = VA \rightarrow 0.706 = 1.5 * A \rightarrow A = 0.47\ m^2$

dia → circular $\rightarrow A = \pi r^2 \rightarrow \frac{0.47}{\pi} = r^2 \rightarrow r = 0.38\ m$

$\rightarrow$ dia = 0.77 m.

The End