Qualifying Examination (Steel Design)

1. A W12x53 is connected at it ends with the plate shown in Fig.1. Determine the allowable tensile force. All plate materials are Fy=42 ksi, Fu=62 ksi). Fasteners are 7/8-in bolts. (25%)

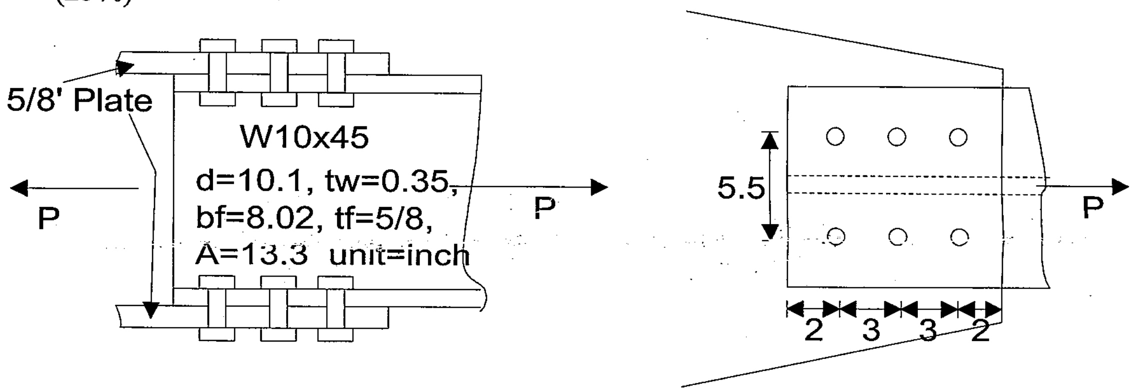


Fig.1 For problem 1 (Unit=inch, A=area inch^2)

2. Do the analysis work for the problem in Fig.2. The member is W12x35, and material is A572 grade 50 steel, Fy=50 ksi. (W12x35, d=12.5, tw=0.3, bf=6.56, tf=0.52, A=10.3 in^2, rx=5.25, ry=1.54, r_T=1.74, Sx=45.6 in^3, Sy=7.47 in^3; unit=in) (25%)

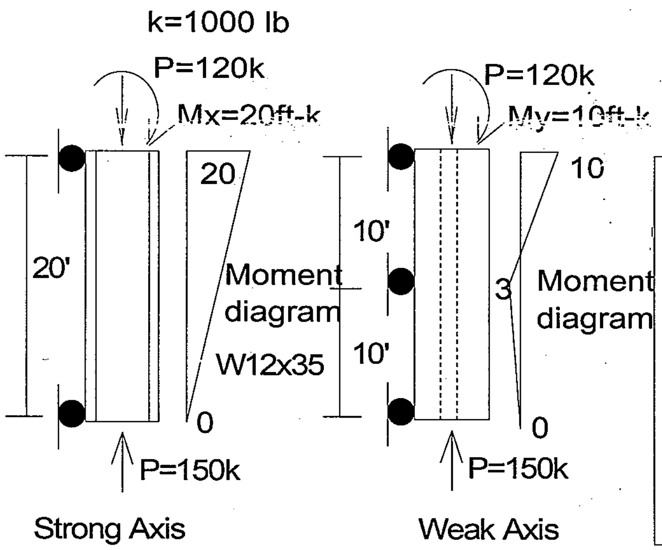


Fig.2

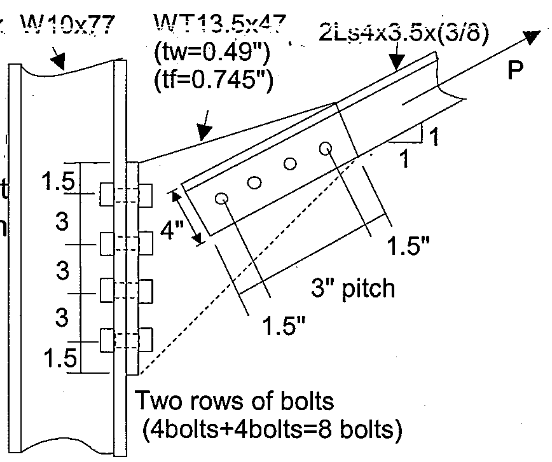


Fig.3

3. Find the maximum P of the structure in Fig.3. The structural steel is A572 grade 50 (Fy=50ksi, Fu=70ksi) and bolt diameter is 1/2". If the bolts are the (1) bearing type (A490X). (2) Slip-critical type (A490SC). You need to check the capacity of the double angles. Do not check plates of the W10x77 column (t_f=0.87"). $F_t = \sqrt{54^2 - 1.82 f_v^{\,2}}$, Tb=15 kips, F_v=21 ksi for A490SC, F_v=40 ksi for A490X, and F_t=54 ksi. (25%)

4. Please explain how to perform the torsion design (or discuss the design procedures for the torsion). (25%)

博士班資格考試「土壤力學」試題　　92,3,28

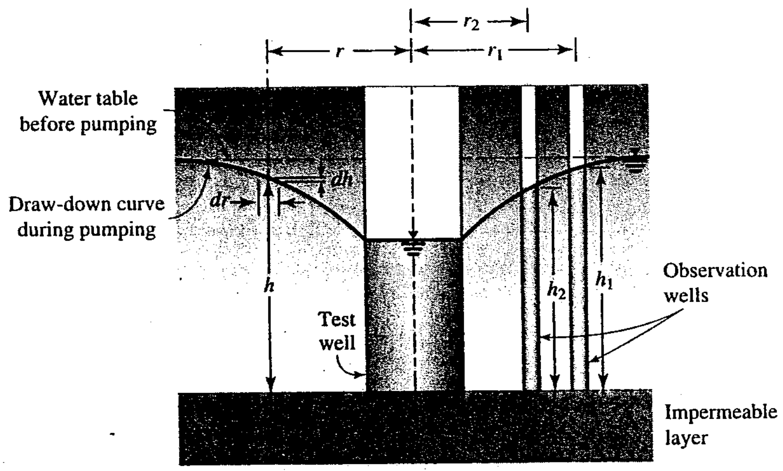
1. 試說明粘土具有塑性之原因？(15%)

2. 何謂標稱(nominal)最大粒徑？在工程上有何用途？又何謂等值粒徑（equivalent size）？（15%）

3. 試說明過壓密粘土如何研判？過壓密粘土的工程特性爲何？（15%）

4. 以砂土進行直接剪力試驗，試體直徑爲 6cm，若破壞時之垂直荷重爲 113.04kg，剪力爲 79.128kg，K_0=0.5，試求初始及破壞時之主應力之大小及方向。(15%)

5. 參考圖一所示之現場抽水試驗示意圖，試推導透水係數 K 之表示式。(20%)



圖一

6.一基礎分別欲構築於飽和正常壓密粘土層上，及飽和過壓密粘土層上，試說明吾人應藉由何等試驗，求得設計所需之相關參數。(20%)

九十一學年度第二學期博士學位資格考

工程地質

Open-book

2003.3.28

1. 從地質材料之觀點歸納台灣之邊坡破壞問題種類及對策。(25 分)

2. 從自然與人為因素探討台灣土石流災害之原因與對策。(25 分)

3. 何謂立體投影圖 (stereoplot)，如何從該圖判斷可能滑動之順向坡及楔形破壞。(25 分)

4. 試述岩體分類法之種類及其特色。(25 分)

國立成功大學土木工程系 91 學年度第二學期博士班資格考試

鋪面工程試題

Openbook

I. 路面檢測　[共 30%]

1. 請說明 Road Rater、FWD、Benkelman Beam 等檢測法的差異(10%)
2. FWD 英文全名爲何? (5%)；FWD 量測值最常見的用途爲何？(5%)
3. 請分類並概略說明這些 FWD 量測值應用程式的原理與分類？(10%)

II. 鋪面分析 [共 20%]

假設高速公路局擬對某路段進行鋪面結構有限元素分析，以研判鋪面是否仍足以承擔未來五年的交通量。但囿於經費，擬以免費的 KENSLAB 或 ILLI-SLAB 程式進行分析，請回答下列問題:

1. 使用該程式時，您建議應該注意哪些重點盡量減少模擬誤差？(5%)
2. 解讀分析結果時，您預期路面變形量會被高估或低估？請條列原因。(10%)
3. 您會不會建議改用其他程式？請條列原因。(5%)

III.鋪面管理系統 [共 25%]

1. 鋪面管理系統通常可分爲哪兩個層級？(10%)
2. PSI 是常見的鋪面評估指標，請問 PSI 與 PSR 間有何關係？(5%)
3. 疲勞破壞關係式與鋪面管理系統有何關聯？(5%)應用於哪一個層級？(5%)

IV. 鋪面設計　[共 25%]

1. 一般的工程設計都有安全係數的概念，請問鋪面設計有無安全係數的考慮？請分別從 AASHTO 設計規範與 PCA 設計規範加以說明(10%)
2. 加大面層的厚度通常能夠加強鋪面結構，但是請您分別從剛性鋪面與柔性鋪面說明其副作用。(15%)

成大土木系博士班資格考試 交通工程試題

2003 年 3 月 28 日

請閱讀所附 Hassan ,Easa, and Hailim, Passing sight distance on two-lane highways: review and revision (1996)論文後，回答下列問題：

1. 本論文之要旨為何？
2. 根據本論文，傳統上公路設計時對視距長度計算之設計基本概念為何？
3. 本論文對上述基本概念提出何種指正？
4. 請對本論文提出你的評論。

Pergamon

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PASSING SIGHT DISTANCE ON TWO-LANE HIGHWAYS: REVIEW AND REVISION

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(Received 13 February 1995; in revised form 21 June 1995)

Abstract—Several models have been developed to determine the minimum passing sight distance required for safe and efficient operation on two-lane highways. The American Association of State Highway and Transportation Officials has developed a model assuming that once the driver begins a pass, he/she has no opportunity but to complete it. This assumption is believed to result in exaggerated passing sight distance requirements. Considerably shorter passing sight distance values are presented in the Manual of Uniform Traffic Control Devices and are used as the marking standards in Canada and the U.S.A. More appropriate models have been developed considering the driver's opportunity to abort the pass, and are based on a critical sight distance which produces the same factor of safety whether the pass is completed or aborted. However, these models need to be revised to determine the passing sight distance requirements more accurately and to closely match field observations. In this paper, a revised model for determining the minimum required passing sight distance was developed, based on the concept of critical sight distance and considering the kinematic interaction between the passing, passed, and opposing vehicles. The results of the revised model were compared with field data and showed that the revised model simulates the passing manoeuvre better than the currently-available models which are either too conservative or too liberal. The results showed that the passing sight distance requirements recommended in the Manual of Uniform Traffic Control Devices are sufficient at low design speeds (50–60 k.p.h.) and for manoeuvres involving passenger cars only. For higher design speeds, the Manual of Uniform Traffic Control Devices standards are less than the passing sight distance required for safe and comfortable passes. The deficiency was found to increase with the increase in design speed, and reaches about 36% at a 120-k.p.h. design speed. Based on these results, major revisions to the current Manual of Uniform Traffic Control Devices marking standards are recommended. Copyright © 1996 Elsevier Science Ltd

INTRODUCTION

Sight distance is one of the fundamental elements in achieving safe and efficient operation of highways. The American Association of State Highway and Transportation Officials (AASHTO) and the Transportation Association of Canada (TAC), formerly the Road and Transportation Association of Canada (RTAC), state that the designer should provide sufficient sight distance for the drivers to control the speed of their cars before striking an unexpected obstacle in the travelled way (RTAC, 1986; AASHTO, 1994). Subsequently, highway design standards are established so as to provide sufficient stopping sight distance (SSD) on all highways. Moreover, the capacity of a segment of a two-lane highway, as explained in the Highway Capacity Manual (HCM, 1994), depends significantly on the percentage of segment length where passing manoeuvres are prohibited because the existence of any slow vehicle will generate a queue of other slow vehicles trailing it. Therefore, a passing sight distance (PSD) sufficient for the drivers to pass slow vehicles should be provided at frequent intervals on two-lane highways. However, to apply this recommendation in reality, a lot of research has been undertaken to answer the following question: How long should the required sight distance be?

AASHTO has presented a model for determining the PSD, but, as will be shown later, this model has been criticized by many researchers. Considerably shorter PSD values for marking standards are presented in the Manual of Uniform Traffic Control Devices (MUTCD, 1976, 1988) developed in the U.S.A. by the Federal Highway Adminstration (FHWA) and in Canada by RTAC. As a result of a better understanding of the nature of the passing manoeuvre, Van Valkenberg and Michael (1971) realized the need for a PSD model that considers the trade-off between the sight distance required for the driver to complete or abort the pass. Consequently, experimental and analytical models have been developed to determine the critical PSD which produces the same safety factor whether the pass is completed or aborted.

In this paper, current PSD models are reviewed and the validity of the assumptions utilized in each model is tested. Based on this review, a revised model is developed to determine the required PSD more accurately and to closely match field observations. A selection of model parameters and a comparison between the results of the revised model and existing standards are also presented.

EXISTING MODELS

AASHTO model

Based on the results of field studies conducted in and before 1958, AASHTO (1994) presented a model to calculate the PSD, S, as follows:

$$S = d_1 + d_2 + d_3 + d_4, \tag{1}$$

where: d_1 = the distance travelled by the passing vehicle during the perception–reaction time and during the acceleration to the encroachment point on the left lane (time elapsed = t_1);

d_2 = the distance travelled by the passing vehicle while occupying the left lane (time elapsed = t_2);

d_3 = a clearance distance between the passing and opposing vehicles at the end of the pass; and

d_4 = the distance travelled by the opposing vehicle for two-thirds of the time the passing vehicle occupies the left lane = 2/3 d_2 (time elapsed = t_4 = 2/3 t_2).

The mechanism of the passing manoeuvre and the distances d_1 to d_4 are shown in Fig. 1. Design values for these distances and PSD requirements are given in the AASHTO Green Book (1994). Clearly, the AASHTO model is not free of self-discrepancies. By taking t_4 = 2/3 t_2 instead of $t_1 + t_2$, the model accounts for the driver's ability to abort the pass if any opposing vehicle is seen ahead during the time t_1 + 1/3 t_2. At the same time, by considering d_1 and all d_2 as parts of the PSD, the model assumes that the passing vehicle is committed to complete the pass once it is initiated. Other assumptions utilized in this model were

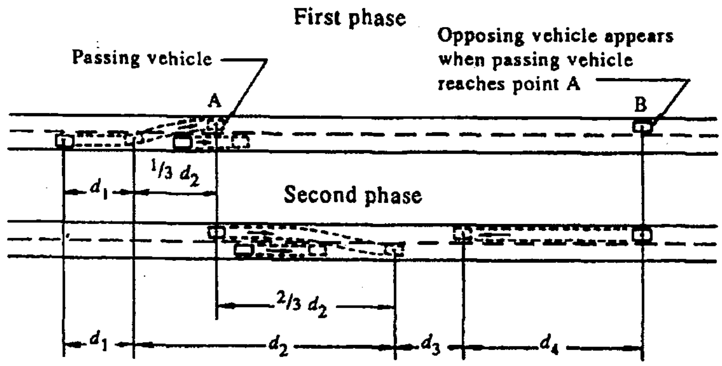


Fig. 1. AASHTO modelling for the passing manoeuvre (AASHTO, 1994).

Table 1. Design and marking standards of passing sight distance in Canada

Speed (k.p.h.)	PSD (m) Design standards (RTAC, 1986)	Marketing standards (MUTCD, 1976)
50	340	160
60	420	200
70	480	240
80	560	275
90	620	330
100	680	400
110	740	475
120	800	565
130	860	—

criticized by Harwood and Glennon (1977) who concluded that 2/3 $d_2 + d_3 + d_4$ would represent a more logical model for PSD. However, such a conclusion was very subjective, and later the authors developed a new model that overcomes the flaws of the AASHTO model (Glennon, 1988; Harwood & Glennon, 1989).

MUTCD design values of PSD

Another discrepancy arises when comparing the PSD values for pavement marking, presented in the Canadian and American versions of MUTCD and those given in the design guides (RTAC, 1986; AASHTO, 1994). A comparison between these values (Table 1) shows that the values used in pavement marking are much shorter than those presented in the design guides. Interestingly, it was reported by Harwood and Glennon (1977, 1989) that the reasons for selecting the minimum sight distances in the MUTCD are not stated, nor is the source given. However, they noted that these values are identical to those presented in the 1940-AASHO Guide. Since these values represent a subjective compromise between PSD for delayed and flying passes, they concluded that these values do not represent any particular passing situation.

Models based on the concept of critical position (point of no return)

A new concept in modelling PSD was presented by Van Valkenberg and Michael (1971). As shown in Fig. 2, they considered that the distance travelled by the passing vehicle can be divided into two distances: the distance during which the vehicle can apply the brakes and pull back into the proper lane (S_0) and the distance required to complete the pass (S_1). They called the point beyond which the pass must be completed *the point of no return*, and based on personal judgement, this point was assumed to occur when the rear bumper of the passed vehicle is abreast of the middle of the passing vehicle. Then, PSD was taken as the sum of S_1 and S_2 plus a clearance distance, where S_2 is the distance travelled by the opposing vehicle during the time required for the passing vehicle to travel the distance S_1. Although Van Valkenberg and Michael (1971) presented design values for PSD based on field measurements, they did not present a mathematical model for their work, and subsequently these measurements can be useful for highways with speeds and conditions within the range used in the field measurements only.

The same concept was used by Lieberman (1982) who called the point of no return the critical position. He defined the critical position as the point where the decision by the

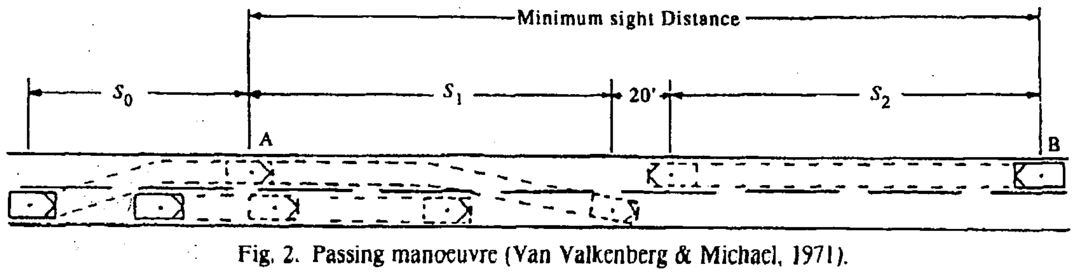


Fig. 2. Passing manoeuvre (Van Valkenberg & Michael, 1971).

passing vehicle to complete the pass will afford it the same clearance relative to the oncoming vehicle as will the decision to abort the pass. He incorporated this definition into a mathematical model to calculate the PSD, but he assumed that the driver is committed to complete the pass, and therefore concluded that the AASHTO criteria for PSD were inadequate. Another attempt for modelling the PSD using the concept of critical position was made by Saito (1984). However, Saito considered only the needs to abort the manoeuvre, and ignored the trade-off between the completed and aborted manoeuvres. Two recent models based on the concept of critical position have been subsequently developed by Glennon (1988) and Rillet *et al.* (1990), and a detailed discussion of these models follows.

Glennon's model

Glennon (1988) presented the most comprehensive and closest modelling to the actual mechanism of the passing manoeuvre. He interpreted the definition of the critical position by having a minimum acceptable headway between the nearest points of each two vehicles involved in the manoeuvre at the end of either a completed or aborted pass. His model was based on the hypothesis that, at the beginning of the pass, the sight distance required to abort the pass is much less than that required to complete it, and vice versa, at the end of the pass. In between, there is a point, the critical position, where the sight distance required to complete the pass equals that required to abort it. Glennon called this sight distance the critical sight distance.

Figure 3 shows the time–space diagram for completed and aborted passes from the critical position (Glennon, 1988). Equating the distance between the front bumper of the passing and impeding vehicles at the critical position, Δ_c, and the critical sight distance, S_c, and assuming 1-s minimum acceptable headway, Glennon formulated his model as follows:

$$\Delta_c = L_P + m\left[\frac{2m + L_I + L_P}{2v - m} - \sqrt{\frac{4v(2m + L_I + L_P)}{d(2v - m)}}\right] \tag{2}$$

$$S_c = 2v\left[2 + \frac{L_P - \Delta_c}{m}\right] = 2v + \frac{2v(L_P + m - \Delta_c)}{m}, \tag{3}$$

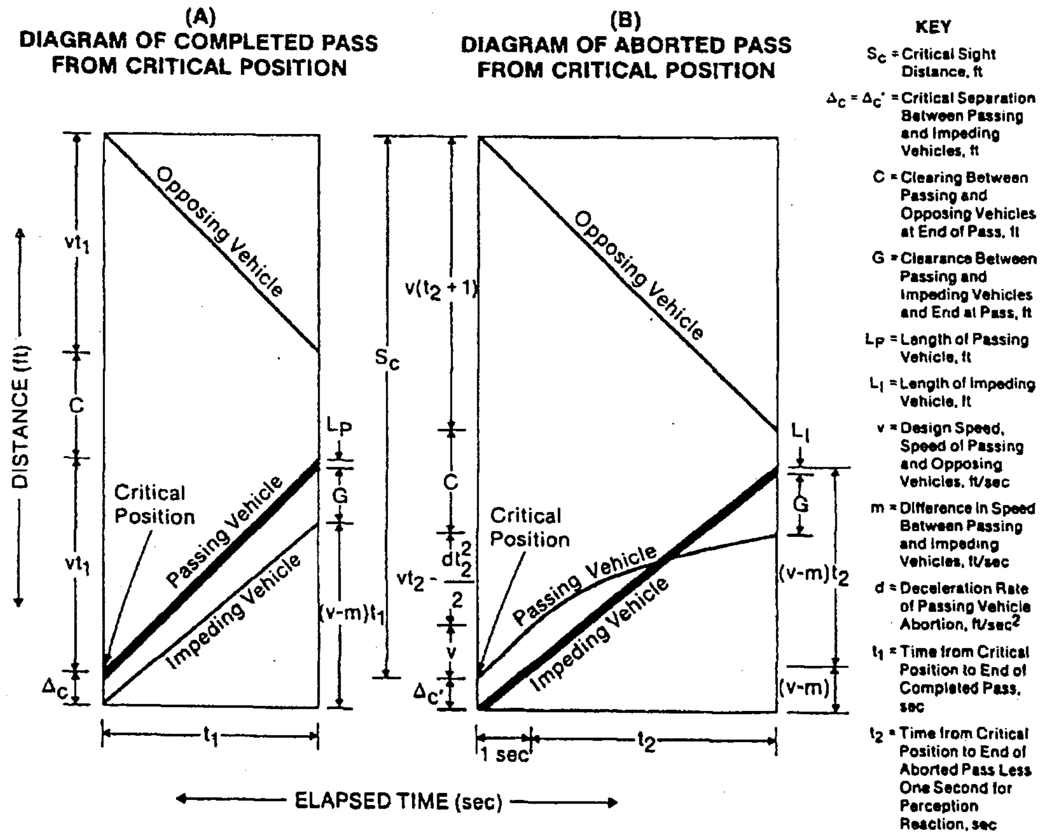


Fig. 3. Time-space diagrams for the critical passing manoeuvre (Glennon, 1988).

where the parameters used in the two equations are explained in Fig. 3.

However, two parameters in this model deserve closer investigation. The first parameter is the clearance, C, between the passing and opposing vehicle at the end of the pass. Although the concept of the point of no return is basically the same as that of the critical position, Van Valkenberg and Michael (1971) identified the point of no return by producing the same *safety factor*, whether the pass is completed or aborted, while Lieberman (1982) identified the critical position by producing the same *clearance* for completed and aborted passes. In the completed pass, the passing vehicle will maintain its speed, v, while decelerating in aborted passes, and thus, having a final speed lower than v. Therefore, if the clearance distance is the same in both cases, the clearance headway in the aborted pass will be greater than that in the completed pass. Undoubtedly, the safety factor depends on the time headway not on the clearance distance. For example, two stationary vehicles will maintain an infinite safety factor, even if the clearance between them is almost zero because the time headway in this case is infinity. Therefore, the definition given by Van Valkenberg and Michael (1971), and interpreted by Glennon (1988), by assuming a minimum acceptable headway between the two vehicles at the end of the pass, appears to be more reasonable. However, in his model, Glennon assumed that the clearance C is constant for completed and aborted passes. This is, of course, in disagreement with the more reasonable definition of the critical position and its interpretation by a minimum acceptable headway. Generally, if two vehicles are travelling in opposite directions with speeds v_1 and v_2, the clearance C which makes them reach the same point after a headway h will be $(v_1 + v_2)h$.

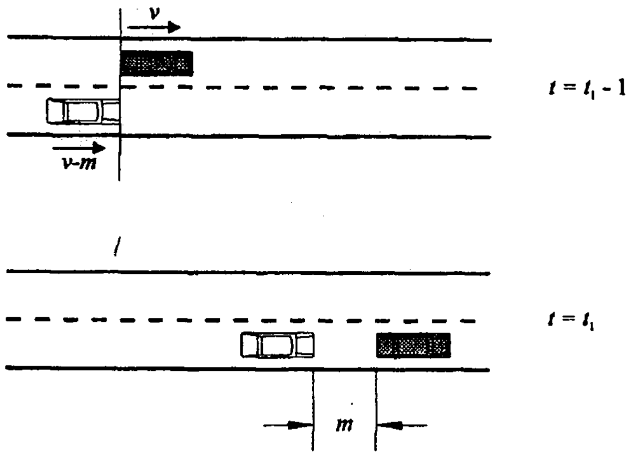
The second parameter is the gap, G, between the passing and impeding vehicles at the end of the pass. In the model's derivation, Glennon stated "Assuming a minimum acceptable headway of 1 s for G, then $G = m$". Although this equality may theoretically be true in some cases, it seems to be unrealistic. As shown in Fig. 4, knowing that the total time required to abort the pass is $t_2 + 1$ s (for perception–reaction time) and the time required to complete the pass is t_1, for the value of G to equal m (times 1 s), one has to assume:

(1) For a completed pass, at time $t = t_1 - 1$, the rear bumper of the passing vehicle is abreast of the front bumper of the impeding vehicle. Then, from this position, the driver of the passing vehicle will initiate the lateral shift of one lane width, to return back to the right lane, and complete it in 1 s.

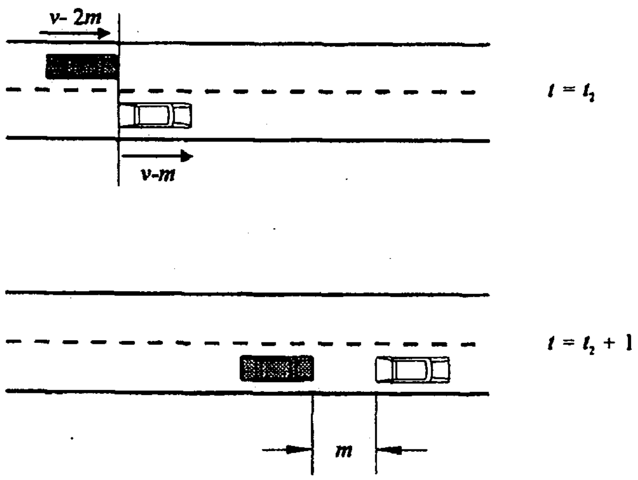
(2) For an aborted pass, at time $t = t_2$, the rear bumper of the impeding vehicle is abreast of the front bumper of the passing vehicle, and the passing vehicle, will travel at a constant speed of $(v - 2m)$ for the remaining 1 s (note that the speed of the impeding vehicle is $v - m$). Also, the driver of the passing vehicle will initiate the lateral shift from this position and complete it in 1 s. Another possible scenario for an aborted pass is as follows: the passing vehicle will continue decelerating during the entire time period t_2. Obviously, G, in this case, cannot be related to m.

Both these assumptions are difficult to justify or accept. It is obvious that initiating the lateral shift from the positions stated above is very hazardous. Actually, the driver of the passing vehicle will maintain some gap distance between his/her vehicle and the impeding vehicle before initiating the pass. Subsequently, for G to equal m, the driver has to complete the lateral shift in a time much less than 1 s.

Moreover, as defined in the Highway Capacity Manual (HCM, 1994), the headway is the time between successive vehicles as they pass a point on a lane or roadway. [Note that the headway as defined in the HCM is measured from front bumper to front bumper, while in Glennon (1988), it is measured from rear bumper to front bumper.] As shown in Fig. 5, if an observer measures the time spacing between the passage of the passing and the impeding vehicle at the end of a completed pass, it will be $m/(v - m)$ which is much lower than 1 s for speeds higher than $2m$. For an aborted pass, the time spacing will be m/v_f, where v_f is the final speed of the passing vehicle due to deceleration. Although the time spacing in this latter case is greater than the corresponding time for a completed pass, it will remain smaller than the 1 s minimum acceptable headway assumed by Glennon (1988), for high speeds where $v_f > m$. The physical interpretation of such very low headway is that the driver of the trailing vehicle



(a) Completed Pass



(b) Aborted Pass

Fig. 4. Assumptions required for $G = m$.

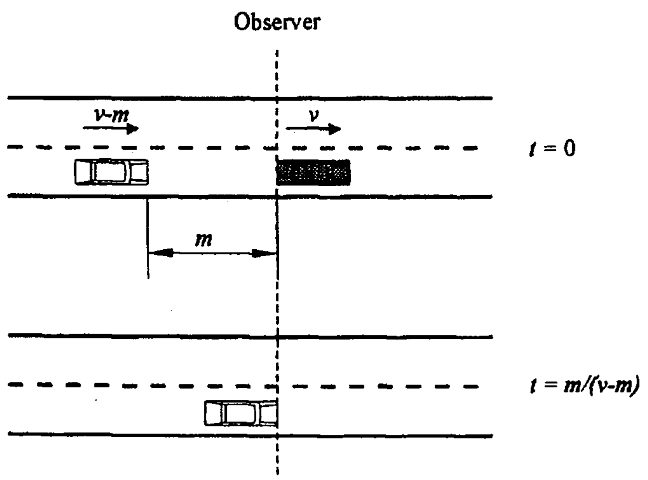


Fig. 5. Actual headway at the end of a completed pass.

will not have any opportunity to decelerate if the leading vehicle stops suddenly unless his/her perception–reaction time approaches zero. As shown in Fig. 6, a more reasonable gap distance, G, between two vehicles having different speeds, v_1 and v_2, where $v_1 > v_2$ and v_1 is the speed of the leading vehicle, and for a headway of h s is v_2h. Therefore, the values of C and G in the model should be based on the speeds of the vehicles involved.

Rillet et al. model

Rillet *et al.* (1990) revised some of Glennon's assumptions and developed a modified model. The main points addressed in the model are:

(1) The value of G in either a completed or aborted pass was related to the speed $(v - m)$ rather than the differential speed m used in Glennon's model.
(2) In aborting the pass, the passing vehicle was assumed to decelerate to a minimum terminal speed, v_{min}, and then maintain this speed until it is back in the right lane.
(3) When reaching the critical position, the passing vehicle may have not yet completed the acceleration to reach the speed v.

Consideration of these assumptions resulted in PSD requirements much longer than those resulting from Glennon's model. However, a closer inspection of the modified model by Rillet *et al.* reveals the following:

(1) In developing the model, Rillet *et al.* stated "A correct approach would be to multiply the time headway by the speed of the slower moving vehicle, $(v - m)$". However, since the passing vehicle in aborted passes decelerates to a speed lower than the speed of the impeding vehicle, $(v - m)$ in this case will represent the speed of the faster vehicle. Therefore, a more appropriate approach would be to multiply the time headway by the speed of the trailing moving vehicle.
(2) The assumption of a minimum terminal speed appears to be too conservative. In a study conducted by TAC (Good *et al.*, 1991), it was stated "it seems illogical to assume that drivers, having determined that a situation exists in which there is potential for an accident (i.e. an oncoming vehicle), will decelerate gradually, and then stop decelerating even though they are not in a position to re-integrate themselves into the traffic stream".
(3) This conservative approach in considering the aborted passes pushes the critical position back, i.e. closer to the beginning of the pass, as the design speed increases. Consequently, the possibility of having the passing vehicle reaching the critical position, while still accelerating, increases. This explains the observation by Rillet *et al.* that "the acceleration at the critical point is still occurring at design speeds of up to 100 km/h when the impeding vehicle is a car (5 m long)".

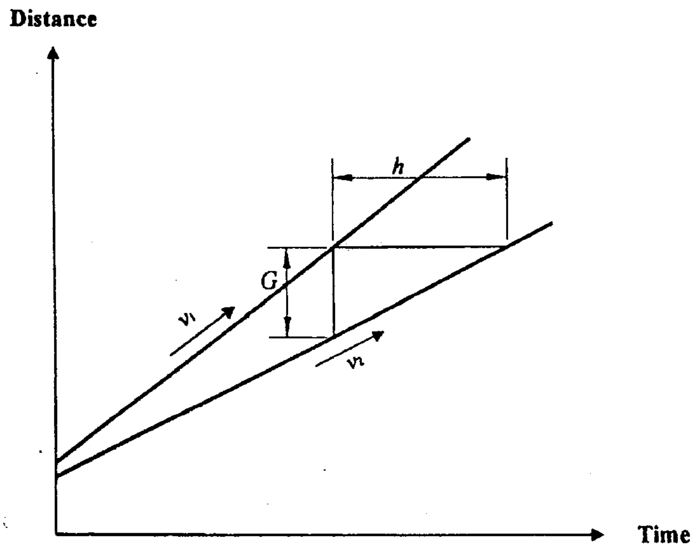


Fig. 6. Time–space relationship for two vehicles with speeds v_1 and v_2.

(4) Although the model successfully considered the acceleration occurring at and beyond the critical position in completed passes, it failed to consider the same event in aborted passes. Instead, the speed of the passing vehicle during the perception–reaction time in aborted passes was assumed to be constant.

REVISED MODEL

Mechanism of the passing manoeuvre

Based on the previous discussion, an ideal passing manoeuvre should proceed as follows: First, the manoeuvre is initiated as follows:

— The impeding and the opposing vehicles are travelling at a constant speed of $v - m$ and v, respectively, during the entire manoeuvre.
— At the beginning of the pass, the passing vehicle is trailing the impeding vehicle and travelling at a speed of $v - m$.
— Then, the passing vehicle accelerates with a constant rate, a, to a speed v, while shifting to the left lane. The sight distance required at this stage is minimal and corresponds to aborting the pass safely.
— As the pass builds up, the sight distance required for the passing vehicle to abort the pass increases and that required to complete the pass decreases.

Second, if the manoeuvre cannot be completed safely, it should be aborted as follows:

— If, at any instance, the driver of the passing vehicle decides to abort the pass, a minimum headway, h_I, should be maintained between the front bumper of the passing vehicle and the rear bumper of the impeding vehicle. Similarly, a minimum headway, h_o, should be maintained between the front bumper of the passing vehicle and the front bumper of the opposing vehicle.
— In aborting the pass, the driver of the passing vehicle takes a perception–reaction time, P, before applying the brakes. During this perception–reaction time, the speed profile of the passing vehicle is assumed to be not influenced by the need to abort the pass.
— Then, the vehicle keeps decelerating with a constant rate, d, until it is back in the right lane.

Finally, at a certain point (the critical position), the sight distance required to abort the pass equals that required to complete it. The sight distance at this point is called the critical sight distance, and the following characteristics are satisfied:

— By reaching the critical position, the passing vehicle had already accelerated to the design speed, v (this assumption will be examined later).
— By passing the critical position, the passing vehicle can complete the pass safely.
— At the end of the completed pass, the minimum headways, h_o and h_I, should be maintained between the front bumpers of the passing and opposing vehicles and between the rear bumper of the passing vehicle and the front bumper of the impeding vehicle, respectively.

Model derivation

The time–space diagram for the revised model is shown in Fig. 7. From the time–space diagram of the completed pass:

$$\Delta_c + vt_I = L_P + G_I + (v - m)t_I, \tag{4}$$

or

$$\Delta_c = L_P + G_I - mt_I, \tag{5}$$

where: L_P = length of passing vehicle;
t_I = time required to complete the pass from the critical position; and
G_I = distance between the rear bumper of the passing vehicle and the front bumper of the impeding vehicle at the end of a completed pass.

Similarly, for an aborted pass:

$$\Delta_c + vP + vt_2 - \frac{d\,t_2^2}{2} = (v - m)(P + t_2) - L_1 - G_2, \qquad (6)$$

or

$$\Delta_c = \frac{d\,t_2^2}{2} - m(P + t_2) - L_1 - G_2, \qquad (7)$$

where: d = deceleration rate of passing vehicle;
L_1 = length of impeding vehicle;
t_2 = time required to abort the pass from the critical position (after the perception and reaction time); and
G_2 = distance between the front bumper of the passing vehicle and the rear bumper of the impeding vehicle at the end of an aborted pass.

By equating Δ_c in eqns (5) and (7):

$$t_1 = P + t_2 - \frac{d\,t_2^2}{2m} + \frac{L_P + L_1 + G_1 + G_2}{m}. \qquad (8)$$

Also, by equating S_c for the completed and aborted passes:

$$t_1 = P + t_2 - \frac{d\,t_2^2}{4v} - \frac{C_1 - C_2}{2v}, \qquad (9)$$

where: C_1 = distance between the front bumper of the passing and opposing vehicles at the end of a completed pass; and
C_2 = distance between the front bumper of the passing and opposing vehicles at the end of an aborted pass.

From eqns (8) and (9):

$$t_2^2\left[\frac{d(2v - m)}{4vm}\right] = \frac{L_P + L_1 + G_1 + G_2}{m} + \frac{C_1 - C_2}{2v}. \qquad (10)$$

As explained earlier, given that the speed of the passing vehicle at the end of an aborted pass equals $(v - dt_2)$, the values of G_1, G_2, C_1, and C_2 will be as follows:

$$G_1 = (v - m)h_1$$

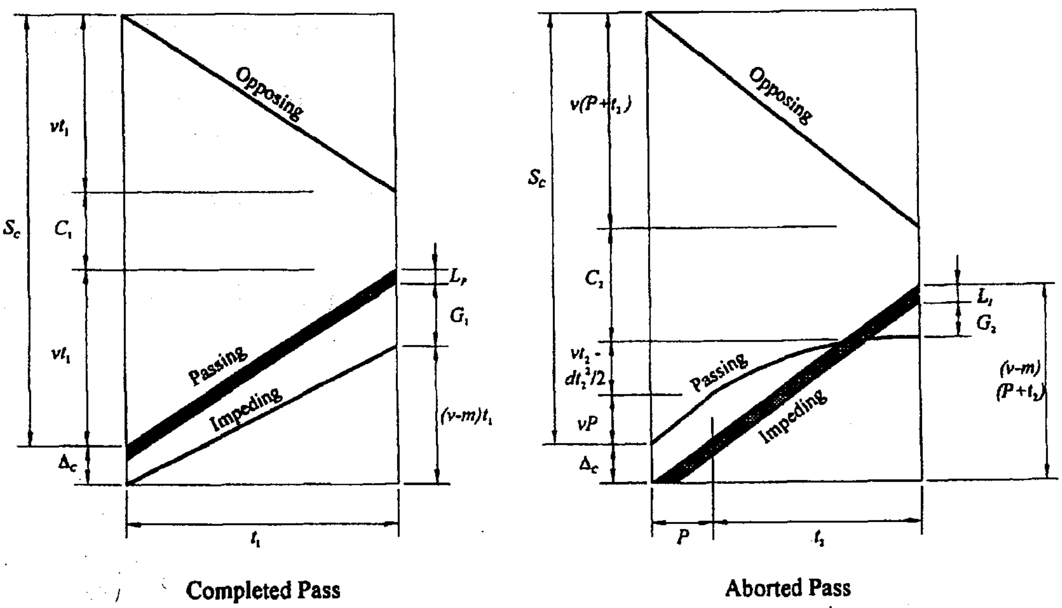


Fig. 7. Time–space diagram for the revised model.

$$G_2 = (v - dt_2)h_l$$

$$C_1 = 2\ vh_o$$

$$C_2 = (2\ v - dt_2)h_o$$

Substituting these values in eqn (10) and solving for t_2:

$$t_2 = -\left[\frac{2vh_l - mh_o}{2v - m}\right] + \sqrt{\left[\frac{2vh_l - mh_o}{2v - m}\right]^2 + \frac{4v[L_P + L_I + (2v - m)h_l]}{d(2v - m)}}. \tag{11}$$

Note that the other possible value of t_2 is negative and thus inadmissible. Substituting for G_1, G_2, C_1, and C_2 in eqns (9), (5) and (6), the equations of t_1 and Δ_c become:

$$t_1 = P + t_2 - \frac{d\ t_2}{4v}(t_2 + 2h_o) \tag{12}$$

$$\Delta_c = L_P + (v - m)h_l - mt_1 = \frac{d\ t_2^2}{2} - m(P + t_2) - L_I - (v - dt_2)h_l. \tag{13}$$

Then, the critical sight distance, S_c, can be formulated as:

$$S_c = 2v(t_1 + h_o) = 2v(P + t_2 + h_o) - \frac{d\ t_2^2}{2} - dt_2h_o. \tag{14}$$

Finally, if $h_o = h_l = h$, eqns (11)–(14) can be written as follows:

$$t_2 = -h + \sqrt{h^2 + \frac{4v[L_P + L_I + (2v - m)h]}{d(2v - m)}} \tag{15}$$

$$t_1 = P + t_2 - \frac{d\ t_2}{4v}(t_2 + 2h) \tag{16}$$

$$\Delta_c = L_P + (v - m)h - mt_1 = \frac{d\ t_2^2}{2} - m(P + t_2) - L_I - (v - dt_2)h \tag{17}$$

$$S_c = 2v(t_1 + h) = 2v(P + t_2 + h) - \frac{d\ t_2^2}{2} - dt_2h. \tag{18}$$

Practical considerations

The analytical solution of the previous equations may produce a positive value of Δ_c which means that the passing vehicle is ahead of the impeding vehicle (Fig. 7). This means that a safe passing manoeuvre may, in some situations, require the driver of the passing vehicle to abort the pass after being ahead of the impeding vehicle. Practically, drivers should not be expected to abide by such a requirement. Therefore, it is recommended that the passing vehicle be provided with the sight distance required to complete the pass when its front bumper is abreast of the front bumper of the impeding vehicle, i.e. at $\Delta = 0$, at most, where Δ is the distance between the front bumpers of the impeding and the passing vehicles.

In this case, the time required for the passing vehicle to complete the pass from the position of $\Delta = 0$ (t_1^*) can be determined by substituting for $\Delta_c = 0$ in eqn (13). Therefore,

$$t_1{}^* = \frac{(v - m)h_l + L_P}{m}. \tag{19}$$

Then, eqn (14) becomes:

$$S_c = \begin{cases} 2v(t_1 + h_o) & \Delta_c \le 0 \\ 2v(t_1{}^* + h_o) & \Delta_c > 0. \end{cases} \tag{20}$$

Selection of model parameters

Differential speed (m). In the AASHTO design guide, the differential speed, m, was set as a constant value of 15 k.p.h., regardless of the design speed, v. On the other hand, based on field studies, speed-dependent values of m were assumed by Glennon (1988) and Harwood and Glennon (1989). These values can be related to the design speed, V, using the following formula:

$$m = 24 - V/10, \tag{21}$$

where m and V are in k.p.h.

Deceleration rate (d). Although the deceleration rate of the passing vehicle, d, in the presented model is assumed constant, an iterative procedure can be used to account for a speed-dependent deceleration rate as follows:

(1) Assume an initial value for the deceleration rate, d.
(2) Calculate t_2 as shown in eqn (11).
(3) Calculate the final speed of the passing vehicle, v_f, as $(v - dt_2)$.
(4) Select an appropriate model for the speed-dependent deceleration rate (French, 1982; Olson *et al.*, 1984; AASHTO, 1994) and determine the average deceleration rate corresponding to these initial and final speeds.
(5) Continue the iterations until the change in the value of d in two successive iterations is within the required accuracy.

Among the different available models for deceleration, the model presented by Olson *et al.* (1984) for a worn tyre to 2/32 inches and operation with steering control should provide a sufficient braking distance for virtually all the vehicles on a highway. Therefore, it is recommended in this paper. According to this model, the average deceleration rate from the design speed, v, to the final speed, v_f, can be calculated as follows:

$$d = \frac{v^2 - v_f^2}{2(BD_0 - BD_f)}, \tag{22}$$

where BD_0 and BD_f are the braking distances (in meters) corresponding to v and v_f, respectively.

Table 2 shows the braking-distance data for a passenger car with a worn tyre and decelerating with steering control. The braking distance corresponding to any speed can be calculated using Gauss interpolation. However, because these data were developed assuming a locked-wheel condition for speeds lower than 32 k.p.h. (20 m.p.h.) (Olson *et al.*, 1984), only the braking distance corresponding to higher speeds is to be used in calculating d. This can be done by imposing a maximum deceleration rate that corresponds to deceleration from the design speed to 32 k.p.h. Finally, to avoid the situation where the passing vehicle decelerates to an unreasonably low speed, the final speed at an aborted pass can be set to a minimum value, v_f. This can be done by reducing the value of d to allow deceleration during the entire time interval t_2 and maintaining the final speed v_f.

Acceleration rate (a). Although the acceleration rate a is not a parameter in this model, it was used to check the assumption that the passing vehicle had completed the acceleration by

Table 2. Braking distance for a passenger car with tyres worn to 0.16 cm (2/32 in) in operation with steering control (Olson *et al.* 1984)

Speed (k.p.h.)	Braking distance (m)
32	13.72
42	33.53
64	65.84
80	115.82
97	188.67
113	287.43
129	416.05

the time it reached the critical position. The values of a can be directly taken from the AASHTO design guide. Another model was developed by Glauz *et al.* (1980) can also be used. According to this model, the acceleration rate, a (m/s^2), can be calculated at an arbitrary speed, v_a (m/s), as follows:

$$a_0 = 1.14\left[\frac{2 - e^{(-42.55R)}}{1 - e^{(-42.55R)}}\right] \tag{23}$$

$$v_m = \frac{a_0}{0.085} \tag{24}$$

$$a = a_0(1 - v_a/v_m), \tag{25}$$

where: R = mass-to-power ratio (kg/W);
a_0 = maximum acceleration (m/s^2); and
v_m = maximum speed (m/s).

However, because the speed decreases continuously upon deceleration, an average speed ($v - m/2$) can be used to calculate the acceleration rate. Also, a low power-to-mass ratio of 40 W/kg which represents a relatively poor performance is recommended for passenger cars to account for most of the vehicles. However, because such a vehicle cannot operate at high speeds (the maximum speed 121.9 k.p.h.) and because this model tends to underestimate acceleration capability at high speeds (Glauz *et al.*, 1980), the acceleration rate corresponding to a 100 k.p.h. design speed was assumed to be the same for higher speeds.

Vehicle length. The vehicle length is extremely variable. However, a design length of 5 m can be assumed for passenger cars. On the other hand, the length of a design truck can be taken as 25 m which is the maximum truck length on Canadian roads (Good *et al.*, 1991).

VALIDATION AND COMPARISON

Validation with field data

In order to test the validity of different models, the PSD requirements resulting from Glennon's model (Glennon, 1988), the modified model (Rillet *et al.*, 1990), and the revised model presented in this paper are compared with the field measurements presented by Van Valkenberg and Michael (1971). In the study by Van Valkenberg and Michael, the distance travelled by the passing vehicle from the point of no return until it returns to the right lane and the time elapsed during travelling this distance were measured for three different speeds of the passed vehicle. The measurements were classified into four types of passes: accelerative with voluntary return, accelerative with forced return, flying with voluntary return, and flying with forced return. The sight distance was calculated, assuming an opposing vehicle travelling with a speed greater than the average speed by 11.2 k.p.h. (7 m.p.h.) and a head-on clearance of 6.1 m (20 ft) at the end of the pass.

The three models were used to determine the required PSD for each speed of the passed vehicle according to the following assumptions:

(1) Only the accelerative passes were considered because all the models assume that the passing vehicle is trailing the passed vehicle at the beginning of the manoeuvre.
(2) The deceleration rate was taken so as to simulate the operation with steering control for a passenger car with tyres worn to (0.16 cm) (2/32 in) modeled by Olson *et al.* (1984). These rates were 2.14, 1.88, and 1.55 m/s^2 for the speeds 77.25, 90.12, and 111.04 k.p.h., respectively.
(3) The speed differential, m, was assumed, as shown in Table 3 (Glennon, 1988).
(4) The minimum headway, h, between the passing vehicle and both the impeding and passing vehicles was taken as 1 s.
(5) The clearance between the passing and opposing vehicle at the end of the pass was taken as $2vh$ instead of the 6.1 m (20 ft) assumed by Van Valkenberg and Michael.

Table 3. Speed differential, m, in passing manoeuvres (Glennon, 1988)

Design speed, V (k.p.h.)	Differential speed, m (k.p.h.)
64	17.70
80	16.09
97	14.48
113	12.87

Table 4. Initial acceleration in passing manoeuvres (AASHTO, 1994)

Speed group of passing vehicle (k.p.h.)	Average acceleration (k.p.h./s)
50–65	2.25
66–80	2.30
81–95	2.37
96–110	2.41

(6) The acceleration rate used in the modified model (Rillet *et al.*, 1990) was assumed according to the values given by AASHTO (1994) for the initial acceleration in the passing manoeuvre (Table 4).
(7) The results of the three models and the field measurements are shown in Fig. 8 for Glennon's model (1988), the modified model (Rillet *et al.*, 1990), and the revised model presented in this paper. The field measurements presented by Van Valkenberg and Michael (1971) are shown for voluntary return and forced return.

As shown in Fig. 8, the PSD requirements resulting from Glennon's model are closer to the forced return performance indicating uncomfortable or unsafe manoeuvring. On the other hand, the PSD requirements resulting from Rillet's modified model are much longer than those required for safe and comfortable manoeuvring, indicating that the model is too conservative. These conservative results are not justified by field observations. The revised model developed in this paper provides PSD requirements that are very close to the voluntary return field data, and therefore ensures safe and comfortable passing manoeuvres. Interestingly, the margin of safety and comfort of PSD requirements produced by the revised model increases as the design speed increases, and thus, the degree of potential hazards due to human errors or shifting from the model's assumptions increases. An

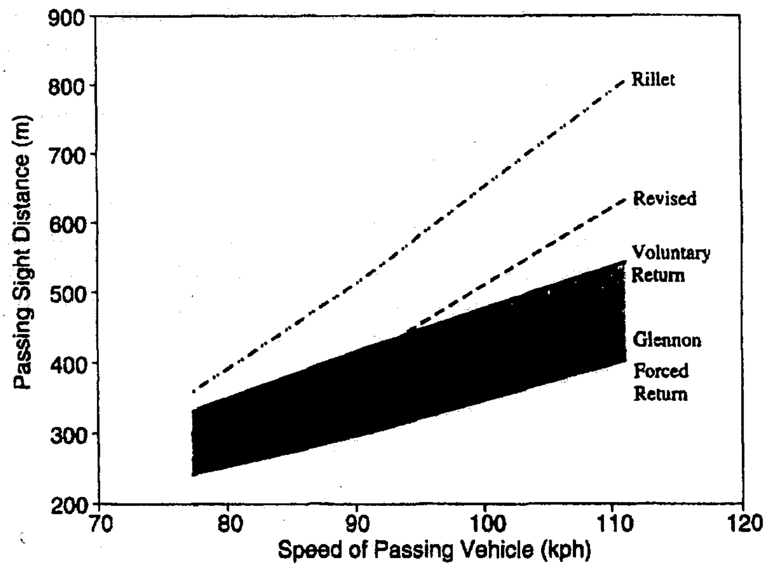


Fig. 8. Comparison between different models and field data.

example of shifting from the model's assumptions is a higher perception–reaction time due to any type of impairments (fatigue or drunkenness). This margin of safety would overcome these hazards.

Comparison with existing standards

A comparison between the PSD which can be obtained by the revised model developed in this paper and the existing design and marking standards was made. With the model parameters selected as explained earlier and a constant minimum headway of 1 s, the PSD requirements developed by the revised model for a passenger car passing a passenger car and a truck are shown in Fig. 9. The figure also shows the PSD requirements recommended in the design standards (RTAC, 1986) and the marking standards (MUTCD, 1976). To examine the assumption of having the passing vehicle completed its acceleration before reaching the critical position, an iterative procedure was used to determine the PSD requirements considering the continuing acceleration. It was found that considering the acceleration at the critical position does not affect the required PSD for speeds higher than 50 k.p.h. Furthermore, considering the acceleration reduced the required PSD at a 50-k.p.h. design speed by only 1 m. Therefore, the assumption of having the passing vehicle completed its acceleration before reaching the critical position is justified, and the simple model presented in the paper is satisfactory.

As shown in the figure, the PSD requirements when the impeding vehicle is a truck are longer than those when the impeding vehicle is a passenger car for speeds up to 110 k.p.h. For higher speeds, there is no difference because the critical position was set as $\Delta = 0$ instead of Δ_c which was positive at higher speeds. As expected, this process would produce PSD requirements which are independent of the characteristics of the impeding vehicle. On the other hand, since the values recommended in the design and the marking standards are to be used for any highway, regardless of the traffic composition, both standards fail to consider the effect of the vehicle length. The results also show, in addition to the great difference between the two standards, that the PSD requirements in neither of them would help achieve safe and economic roads. Although following the design standards would guarantee the safety of the passing manoeuvres for all passes up to a 120-k.p.h. design speed, this safety would be achieved in an expensive way. On the other hand, following the MUTCD standards would jeopardize the passes involving passenger cars when the design speed is higher than 70 k.p.h. If the impeding vehicle is a long truck, safety would not be achieved for all speeds. It is clear, therefore, that the MUTCD marking standards need major revisions so as to account for the traffic composition on any specific highway and to ensure safety and comfort in all passing manoeuvres.

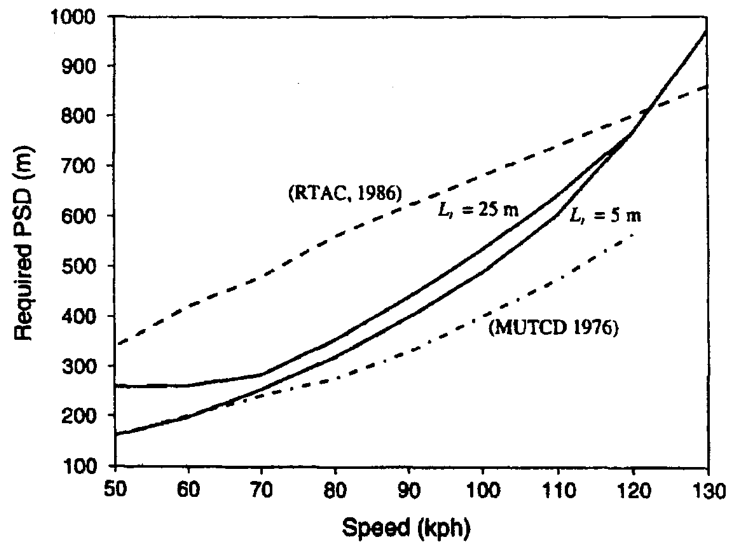


Fig. 9. Comparison between PSD requirements of the revised model and current marking and design standards.

CONCLUSIONS

In this paper, different analytical models for calculating the required sight distance for safe and comfortable passing on two-lane highways were reviewed and examined. It was shown that each of these models contains some inappropriate assumptions resulting in either longer or shorter PSD requirements than those actually needed. A revised model was presented and validated using field data. The model provides a margin of safety for the passing manoeuvres that increases with the increase in the design speed, and therefore would overcome any deviation for any of the parameters from its design value. The assumptions used in the model were tested to ensure the simplicity of the model without compromising its accuracy. The results of the revised model suggest that major revisions of the MUTCD marking standards are needed. These revisions can be established using the revised model based on prevailing traffic characteristics and vehicle performance on each highway. It should be noted, however, that the revised model was validated using only one set of field data, and more data should be collected for further validating the model and updating the values of its parameters.

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路面材料 （總分 100 分，70 分及格）

1. There are several testing equipments to conduct various Superpave physical tests for asphalt binders. Describe the equipments and the related purpose for testing, and the related performance parameter being partly influenced by the asphalt binder.（25 分）

2. What material characteristics should be evaluated for the suitability of aggregates in HMA?（25 分）

3. Briefly describe the procedures of the Superpave mix design method. (25 分）

4. Describe what kinds of improvements should be achieved for an ideal HMA pavement binder?（25 分）

混凝土組合律
博士資格考

Spring 2003

1. Derive the creep strain for the Burger model, which is frequently employed to describe the creep behavior of concrete, in terms of the fixed applied stress σ_0, the material parameters E_1, η_1, E_2 and η_2 and time t. (25%)

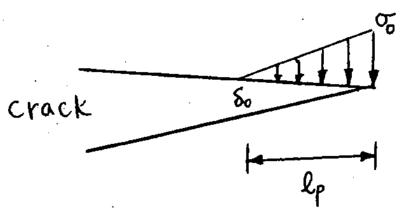
2. Describe (a) the maximum pull-out load versus embedded length (b) the pull-out load versus fiber displacement when the interfacial friction condition is $0 < \tau_{fu} / \tau_{au} < 1$. Here, τ_{au} is the adhesional shear strength and τ_{fu} is the shear stress at the debonded zone in a fiber reinforced concrete. (25%)

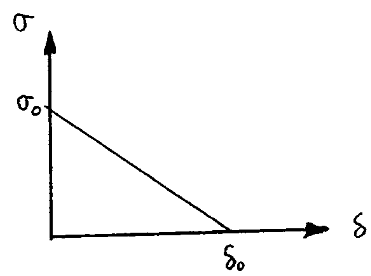
3. Plot and discuss the failure surface of a concrete subjected to bi-axial stresses of $\sigma_{11} = \sigma_{22}$ when one of the following failure criteria is employed: von Mises and Coulomb-Mohr. (25%)

4. The stress intensity factor for a semi-infinite crack extending from x=-∞ to x=0 is given by:

$$K = \sqrt{\frac{2}{\pi}} \int_{-\infty}^{0} \frac{\sigma(x)}{\sqrt{-x}} dx$$

where σ(x) is the traction distributed along the crack face. For the semi-infinite crack, calculate the process zone size for the stress separation curve shown below when propagation is imminent (μ and ν are known). (25%)





第 1 題（50 分）

本題組之主題為 Set covering problem（簡稱 SCP）。

Set covering problem 的定義如下：考慮集合 R={1,2,...,m}以及 H={H_1, H_2, ..., H_n}。其中 H_i 為集合 R 之部份集合，i=1, 2, ..., n。令 c_i 為選取 H_i 時之成本。SCP 的目的在求解如何自 H 中選取若干個元素，使得這些獲選元素之聯集等於 R，且成本總和最小。

(a) (20 分) 試將 SCP 寫成一個整數規畫問題(Integer programming problem)。
(b) (15 分) Set partitioning problem (SPP)與 SCP 類似，但要求 R 中的每一個元素僅能屬於 H 中獲選的元素其中的一個。試將 SPP 寫成一個整數規畫問題。
(c) (15 分) 對同一個 R、H、以及一組 c_i，若其 SCP 以及 SPP 均存在最佳解，是否能預期何者之最佳目標函數值將較高？試說明其理由。

第 2 題（50 分）

本題組之主題為鋼筋裁切問題。

絕大部份的土木工程均需要使用鋼筋。在工程上所需要之各種長度之鋼筋均是利用直徑適當之原料鋼筋裁切成適當之長度而得。

鋼筋裁切問題定義如下。考慮一組長度為 M 之原料鋼筋以及工程所需要之鋼筋 P={p_1, p_2, ..., p_n}。令 c_i 為 p_i 之長度，$c_i \leqq M$。鋼筋裁切問題的目的在求解如何用最少量的原料鋼筋以獲得所有工程需要之鋼筋。為簡化問題，在此假設所有鋼筋之直徑均相同，原料鋼筋之長度均相同、原料鋼筋供應無缺、且裁切無損耗。

(a) (10 分) 試將鋼筋裁切問題寫成數學模式。
(b) (10 分) 試建議鋼筋裁切問題之求解方法。
(c) (15 分) 試就求解時間以及解之品質描述你在(b)小題所提出之求解方法之預期績效。
(d) (15 分) 如果你已有電腦軟體能求解第 1 題組之 SCP 以及 SPP，是否有可能利用此一軟體協助求解鋼筋裁切問題？應如何做？