รายการอ้างอิง

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ภาคผนวก

ภาคผนวก ก

ระยะและขนาดของรถบรรทุกที่นำมาใช้ในการคำนวณหาโมเมนต์ดัดและความเค้น

รายละเอียดของรถยนต์ ฮีโน่ รุ่น FA141 หรือ รถบรรทุกหกล้อ รุ่น Toyota Dyna

ประสิทธิภาพและอัตราทดเกียร์

ตารางที่ ก.1 รายละเอียดของประสิทธิภาพและอัตราทดเกียร์ของรถ

รุ่น		FA141
ความเร็วสูงสุด (กม/ชม.)		112
ความสามารถขึ้นทางชัน (%)		40
อัตราทดเกียร์	เกียร์ 1	5.657
	เกียร์ 2	2.818
	เกียร์ 3	1.587
	เกียร์ 4	1.000
	เกียร์ 5	0.835
	เกียร์ถอยหลัง	5.657
อัตราทดเกียร์เพลาหลัง		6.167

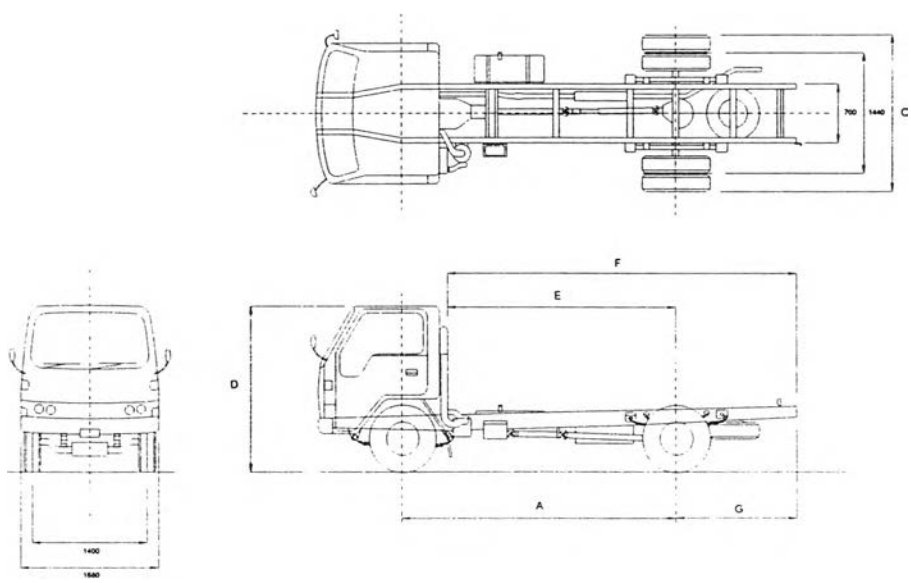
เครื่องยนต์

รุ่น	โตโยต้า 14B
แรงม้าสูงสุด	115 แรงม้า (SAE)
	เมื่อเครื่องหมุน 3,400 รอบ/นาที
แรงบิดสูงสุด	27 กิโลกรัมเมตร (SAE)
	เมื่อเครื่องหมุน 1,600 รอบ/นาที
แบบ	ดีเซล 4 จังหวะ 4 สูบ เรียงตั้งแนวตรง
	ระบายความร้อนด้วยน้ำ
ระบบการเผาไหม้	แบบไดเร็คอินเจ็คชั่น
เส้นผ่าศูนย์กลางกระบอกสูบ × ระยะชัก	102 × 112 มม.
ความจุกระบอกสูบ	3,660 ซีซี.
อัตราส่วนการอัด	18.0

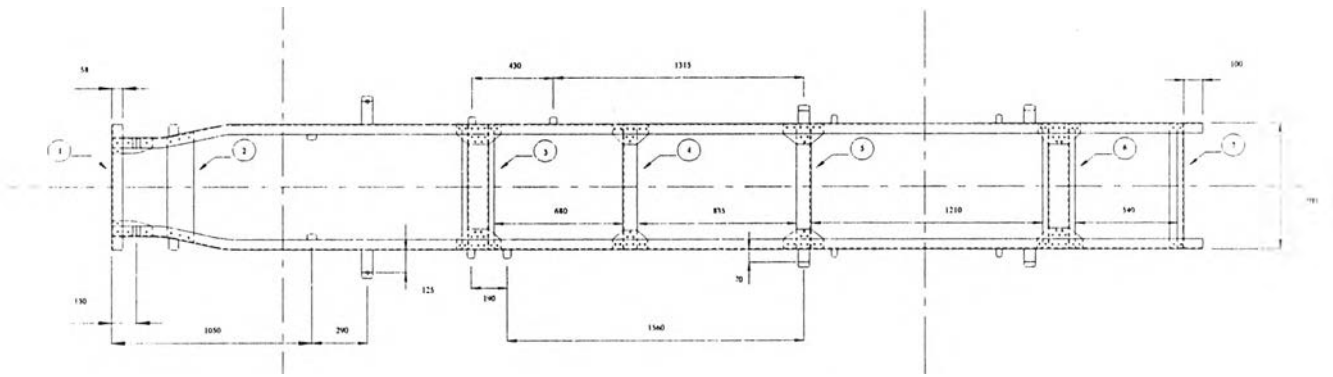
คลัตช์	
แบบ	แห้งแผ่นเดียว ควบคุมด้วยระบบไฮโดรลิค
เกียร์	
แบบ	กระปุก 5 เกียร์ เดินหน้าโอเวอร์ไดรฟ์
เพลาหลัง	
แบบ	ลอยตัวทั้งหมด แบบเบนโจ
รับน้ำหนัก	4,700 กก.
เพลาหน้า	
แบบ	คานเหล็กรูปตัว "I" โค้ง
รับน้ำหนัก	2,400 กก.
ระบบเบรก	
แบบ	ระบบไฮโดรลิค ประกอบด้วยก้ามเบรกแบบตัวนำกระทำที่ทุกล้อ
การควบคุม	2 วงจรอิสระ
เบรกมือ	
แบบ	กลไกเบ่งตัวเบรก กระทำที่เพลากลาง
เบรกไอเสีย	
แบบ	ทำงานด้วยสุญญากาศ ใช้ไฟฟ้าบังคับ
ระบบพวงมาลัย	
แบบ	ลูกปืนหมุนวน
อัตราทด	26.3
ระบบกันสะเทือน	
หน้า	แหนบและโช้คอัพ
หลัง	แหนบและแหนบช่วย พร้อมโช้คอัพ
ล้อและยาง	
แบบของล้อ	เส้นผ่าศูนย์กลาง 16 นิ้ว น็อตล้อ 5 ตัว
ขนาดยาง	7.00-16-12 ชั้น
ถังน้ำมัน	100 ลิตร
คานแชสซี	เหล็กรูปขั้นบันได
อุปกรณ์ไฟฟ้า	
แบตเตอรี่	12 โวลต์ 10 แอมแปร์-ชั่วโมง
เครื่องกำเนิดไฟฟ้า	ไฟฟ้ากระแสสลับ 12 โวลต์ 50 แอมแปร์

ตารางที่ ก.2 รายละเอียดของระยะต่าง ๆ ของรถ

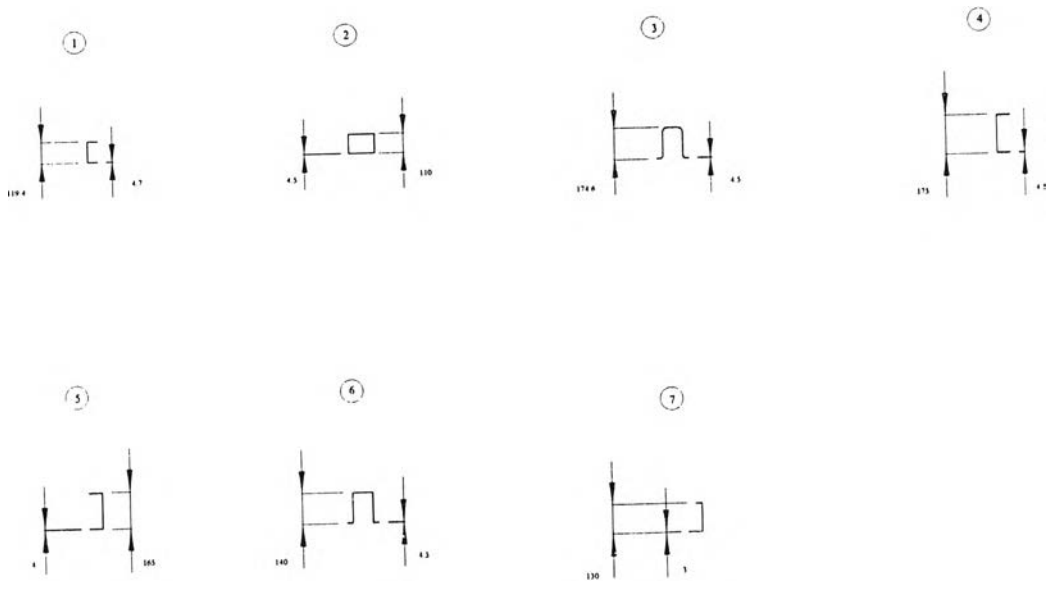
ชื่อรุ่นจดทะเบียน				BU141R-HKMQS3
น้ำหนักรถรวมน้ำหนักบรรทุกGVM.			กก.	6,000
น้ำหนักแชสซี	รวม		กก.	2,000
	หน้า		กก.	1,200
	หลัง		กก.	800
รัศมีวงเลี้ยวแคบสุดที่ยาง			มม.	6,700
ช่วงล้อ		A	มม.	3,365
ความยาวทั้งหมด		B	มม.	5,850
ความกว้างทั้งหมด		C	มม.	1,870
ความสูงทั้งหมด		D	มม.	2,000
ระยะจากหัวเก๋งถึงศูนย์กลางล้อหลัง		E	มม.	2,800
ระยะจากหลังเก๋งถึงปลายเฟรม		F	มม.	4,260
ระยะยื่นหน้า			มม.	970
ระยะยื่นท้าย		G	มม.	1,460
ความสูงของเฟรมที่เพลาหน้า		H	มม.	675
ความสูงของเฟรมที่เพลาหลัง		I	มม.	765
ระยะต่ำสุดของรถ(วัดที่เพลาหลัง)			มม.	195
จำนวนที่นั่ง				3
ขนาดยาง				7.00-16-12 ชั้น



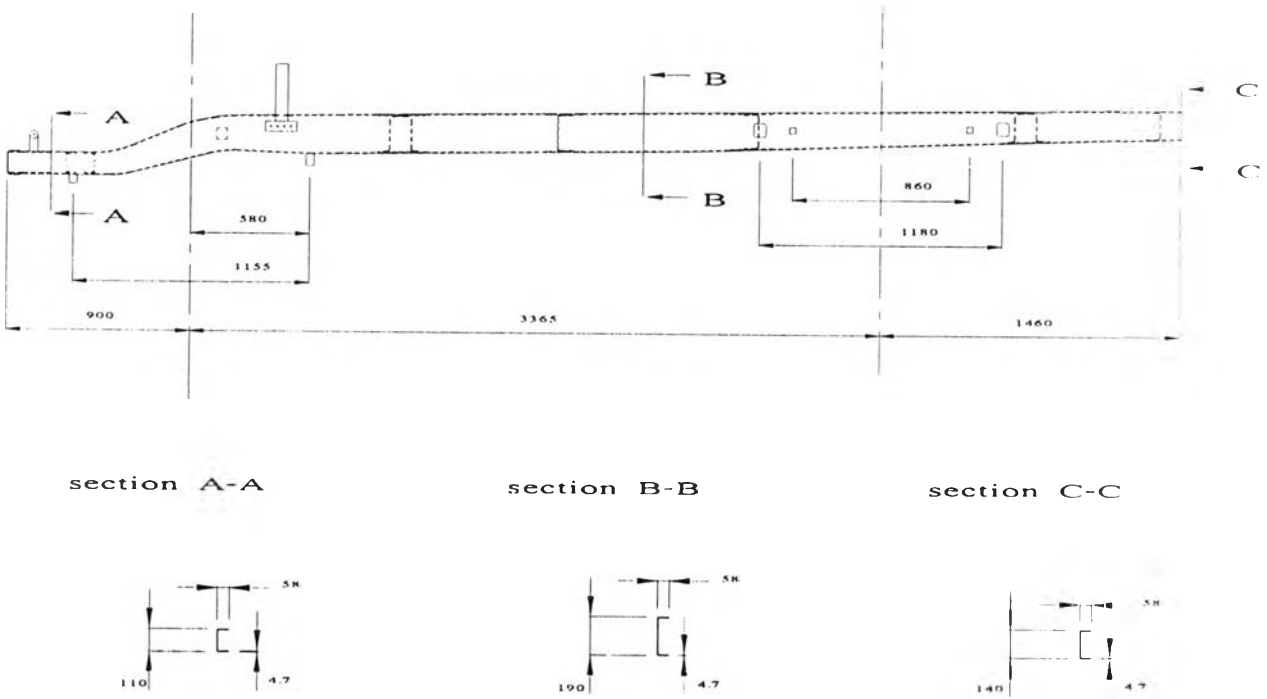
รูปที่ ก.1 ระยะของรถบรรทุกที่ใช้ทดสอบ



รูปที่ ก.2 ระยะของคานตามยาวและตามขวางของรถบรรทุกตัวอย่าง ในหน่วยมิลลิเมตร



รูปที่ ก.3 ขนาดจริงของคานตามขวางของรถบรรทุกตัวอย่าง ในหน่วยมิลลิเมตร



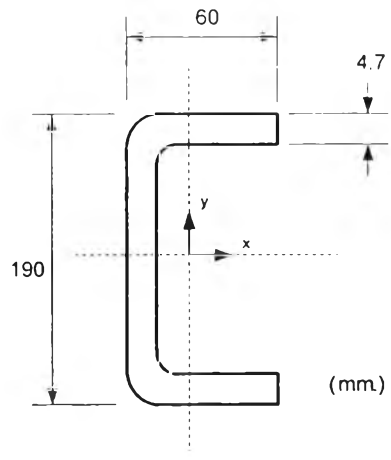
รูปที่ ก.4 ระยะและขนาดจริงของคานตามยาวของรถบรรทุกตัวอย่าง ในหน่วยมิลลิเมตร

ระยะและน้ำหนักที่ใช้ในการคำนวณ

น้ำหนักของกระบะที่บรรทุก		1,000	กิโลกรัม
น้ำหนักห้องโดยสาร		600	กิโลกรัม
น้ำหนักเครื่องยนต์รวมเกียร์		350	กิโลกรัม
น้ำหนักแบตเตอรี่		15	กิโลกรัม
น้ำหนักยางอะไหล่		15	กิโลกรัม
น้ำหนักน้ำมันรวมถัง		110	กิโลกรัม
น้ำหนักลงเพลาหน้าเมื่อบรรทุกเต็มพิกัด		2,000	กิโลกรัม
น้ำหนักลงเพลาหลังเมื่อบรรทุกเต็มพิกัด		4,000	กิโลกรัม
น้ำหนักล้อและเพลาหน้า		200	กิโลกรัม
น้ำหนักล้อและเพลาหลัง		300	กิโลกรัม
ระยะของจุดศูนย์กลางมวลของห้องโดยสารถึงแนวคานตามยาว		500	มิลลิเมตร
ระยะของจุดศูนย์กลางมวลของสิ่งที่บรรทุกถึงแนวคานตามยาวให้เท่ากับความกว้างของโครงกรอบ			
เส้นผ่านศูนย์กลางล้อหน้า		740	มิลลิเมตร
เส้นผ่านศูนย์กลางล้อหลัง		740	มิลลิเมตร
แหนบหน้า			
จำนวน		5	แผ่น
กว้าง		70	มิลลิเมตร
หนา		9	มิลลิเมตร
แหนบหลัง			
แหนบหลัก	จำนวน	8	แผ่น
	กว้าง	70	มิลลิเมตร
	หนา	9	มิลลิเมตร
แหนบช่วย	จำนวน	7	แผ่น
	กว้าง	70	มิลลิเมตร
	หนา	7	มิลลิเมตร
ระยะยุบตัวของยางหน้า		20	มิลลิเมตร
ระยะยุบตัวของยางหลัง(ล้อคู่)		20	มิลลิเมตร

หน้าตัดของคานตามยาวตรงตำแหน่งที่ติดสเตรนเกจ ทั้ง 5 จุด

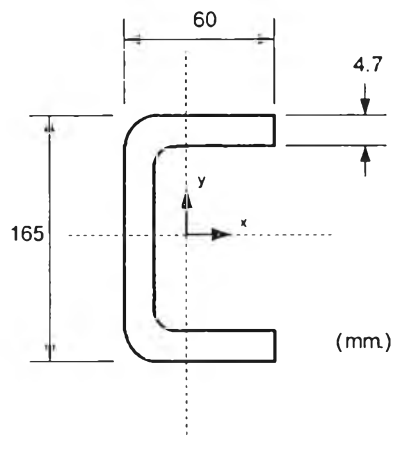
ตำแหน่งที่ 1 และ ตำแหน่งที่ 2



รูปที่ ก.5 หน้าตัดคานตามยาวตรงตำแหน่งที่ติดสเตรนเกจตัวที่ 1 และ 2

โมเมนต์ความเฉื่อยของพื้นที่หน้าตัดรอบแกน x เท่ากับ 7,149,545.145 mm^4

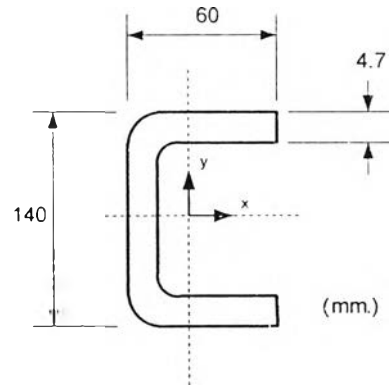
ตำแหน่งที่ 3



รูปที่ ก.6 หน้าตัดคานตามยาวตรงตำแหน่งที่ติดสเตรนเกจตัวที่ 3

โมเมนต์ความเฉื่อยของพื้นที่หน้าตัดรอบแกน x เท่ากับ 5,099,707.9 mm^4

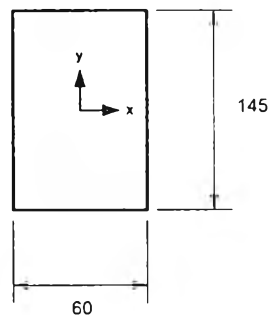
ตำแหน่งที่ 4 และตำแหน่งที่ 5



รูปที่ ก.7 หน้าตัดคานตามยาวตรงตำแหน่งที่ติดสเตรนเกจตัวที่ 4 และ 5

โมเมนต์ความเฉื่อยของพื้นที่หน้าตัดรอบแกน x เท่ากับ 3,454,658.158 mm^4

คานไม้ที่เสริมคานตามยาว



รูปที่ ก.8 หน้าตัดคานไม้ที่เสริมที่คานตามยาวของโครงกรอบ

โมเมนต์ความเฉื่อยของพื้นที่หน้าตัดรอบแกน x เท่ากับ 15,243,125 mm^4

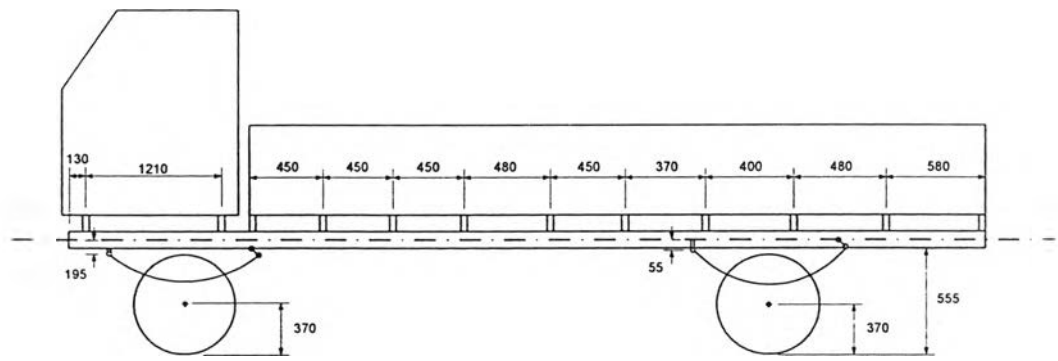
ภาคผนวก ข

ระยะที่ใช้ในการคำนวณหาโมเมนต์ดัดที่เกิดจากแรงกระทำในแนวดิ่งและแนวระดับ

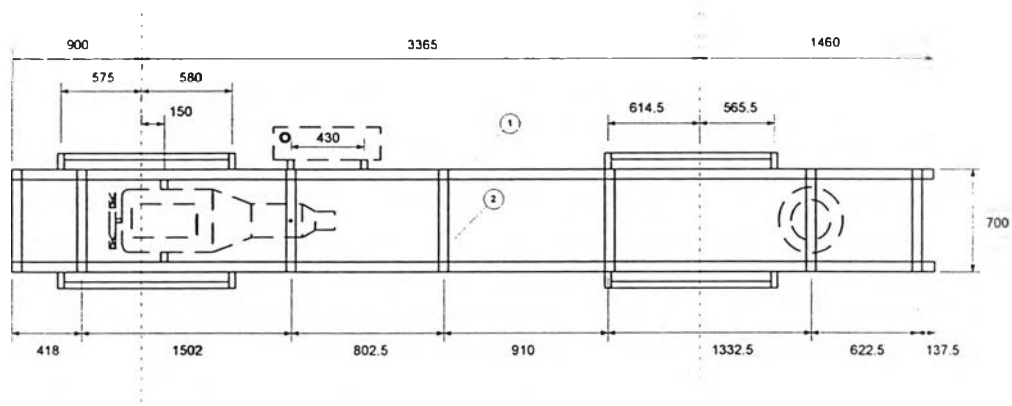
1. ระยะที่ใช้ในการคำนวณหาโมเมนต์ดัดที่เกิดจากแรงกระทำในแนวดิ่ง

ในการคำนวณหาโมเมนต์ดัดที่เกิดขึ้นจะต้องรู้ระยะและขนาดจริงของโมเดลที่จะนำมาใช้ในการคำนวณ ว่ามีระยะต่างๆ เท่าใดจึงจะสามารถนำไปคำนวณหาได้

ระยะและขนาดของคานตามยาวที่ใช้ในการคำนวณจำเป็นต้องมีการปรับระยะบางส่วนจากระยะจริงตามความเหมาะสมเพื่อให้ง่ายต่อการคำนวณ ตามรูปที่ ข.1



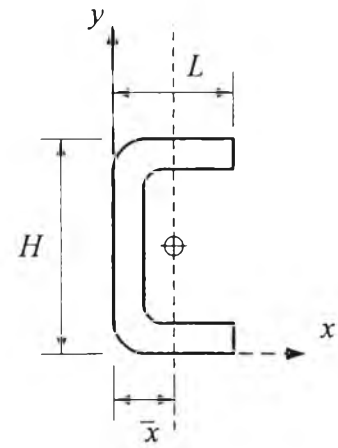
รูปที่ ข.1 ระยะด้านข้างของโมเดลที่ใช้ในการคำนวณหาโมเมนต์ดัด



รูปที่ ข.2 ระยะในแนวระนาบของโครงกรอบที่ใช้ในการคำนวณหาโมเมนต์ดัด

2. ระยะที่ใช้ในการคำนวณหาโมเมนต์ดัดที่เกิดจากแรงกระทำในแนวระดับ

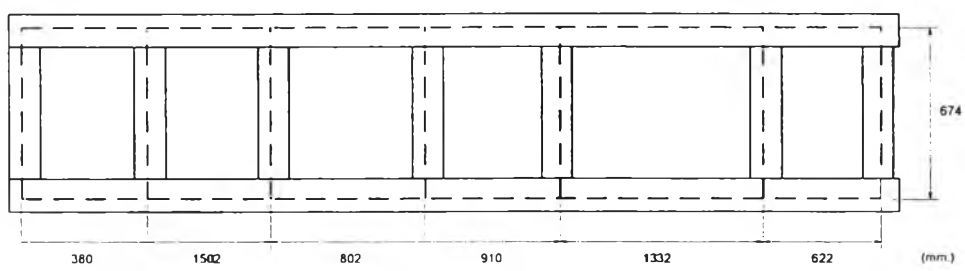
ในการคำนวณหาโมเมนต์ดัดที่เกิดจากแรงกระทำกับโครงกรอบในแนวระดับ จะทำให้เกิดการโก่งตัวในแนวระดับ ซึ่งคานที่ใช้ทำโครงกรอบส่วนใหญ่เป็นคานที่มีหน้าตัดเป็นรูปตัวซี ระยะที่ใช้คือระยะที่แนวของแรงผ่านจุดศูนย์กลางของพื้นที่หน้าตัดของคาน ตามรูปที่ ค.1



รูปที่ ข.3 ตำแหน่งที่แนวของแรงผ่านแล้วจะเกิดแต่การดัดตัว

โดย $\bar{x}$ หาได้จากสมการ $A\bar{x} = \sum A_i\bar{x}_i$ เป็นระยะที่แนวแรงผ่านแล้วจะเกิดแต่การดัดตัว โดยที่ไม่เกิดการบิดตัว

การคำนวณปัญหาที่เกิดการดัดตัวในแนวระนาบจะใช้ระยะตำแหน่งของอุปกรณ์ที่ติดตั้ง ระยะของคานตามยาวและคานตามขวางในการคำนวณ ระยะที่ได้จากโครงกรอบจริงจึงต้องมีการปรับระยะใหม่ เพื่อให้เข้ากับวิธีการคำนวณ ตามรูปที่ ข.4



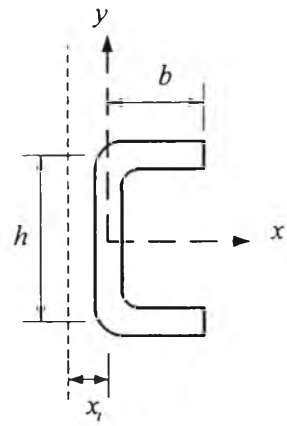
รูปที่ ข.4 ระยะของโครงกรอบที่ใช้ในการคำนวณปัญหาที่เกิดการดัดตัว

ในรูปที่ ข.4 แสดงระยะของโครงกรอบในแนวระนาบที่ใช้กับปัญหาการดัดตัวในแนวระนาบ จะใช้ระยะที่แรงส่งผลให้เกิดแต่การดัดตัว โดยที่แรงนั้นไม่ส่งผลให้เกิดการบิดตัวด้วย

ภาคผนวก ค

ระยะที่ใช้ในการคำนวณหาโมเมนต์ดัดที่เกิดจากการบิดตัวของโครงกรอบ

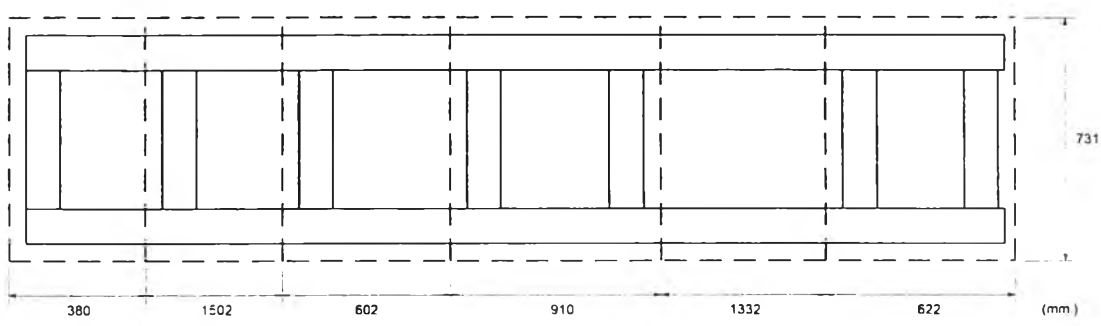
ในการคำนวณหาโมเมนต์ดัดที่เกิดจากการบิดตัวของโครงกรอบรถบรรทุก จะใช้ระยะที่แรงมากระทำแล้วส่งผลให้โครงกรอบเกิดการบิดตัวเพียงอย่างเดียว สำหรับโครงกรอบที่คานมีหน้าตัดเป็นรูปตัวซี ระยะที่ใช้คือระยะที่แนวของแรงผ่านแนวจุดศูนย์กลางของแรงเฉือนของพื้นที่หน้าตัดของคาน ตามรูปที่ ค.1



รูปที่ ค.1 ตำแหน่งที่แนวของแรงผ่านจุดศูนย์กลางของแรงเฉือน

ระยะ x_t หาได้จากสมการ $x_t = \dfrac{b}{2+h/3b}$ เป็นระยะที่แนวของแรงผ่านแล้วจะเกิดแต่การโก่งตัวเพียงอย่างเดียว

ระยะของโครงกรอบในแนวระนาบที่ใช้ในการหาโมเมนต์ดัดในกรณีนี้ต้องมีการปรับจากระยะจริง เนื่องจากในวิธีนี้จะพิจารณาตรงระยะที่แรงทำให้คานเกิดแต่การบิดตัวของโครงกรอบเพียงอย่างเดียว ตามแนวเส้นประในรูปที่ ค.2



รูปที่ ค.2 ระยะของโครงกรอบในการคำนวณหาโมเมนต์ดัดที่เกิดจากการบิดตัว

ภาคผนวก ง

กราฟโมเมนต์ดัดจากการคำนวณที่มาจากภาระในกรณีที่ 1

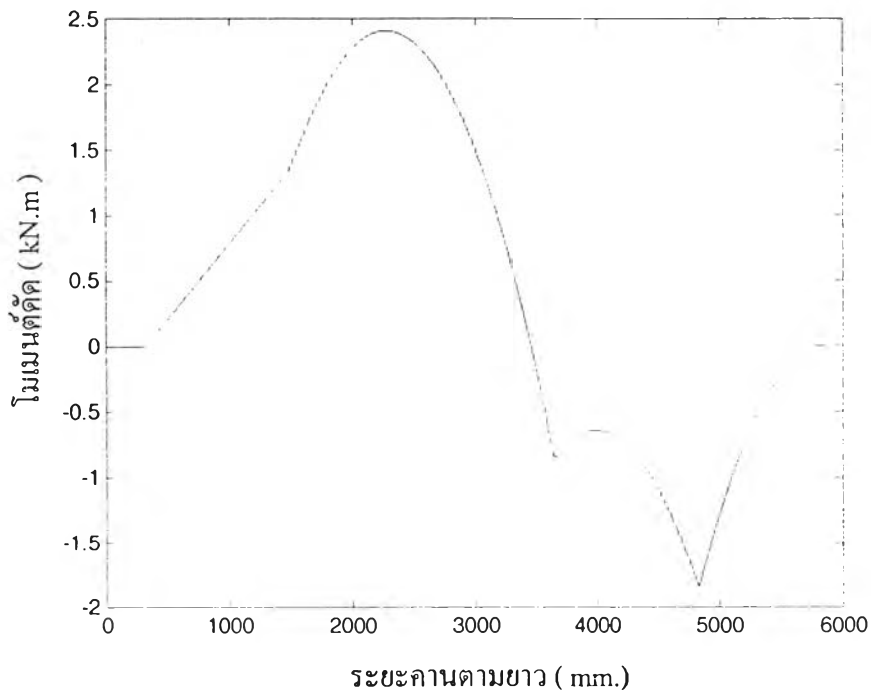
กราฟโมเมนต์ดัดจากการคำนวณที่เกิดขึ้นที่คานตามยาวของโครงกรอบจากการรับภาระในกรณีที่ 1 ในการคำนวณจะให้มีแรงกระทำเหมือนการจัดวางถุงปูนซีเมนต์ให้เหมือนกับการทดสอบทั้ง 3 กรณี คือ

(1) การจัดวางถุงปูนซีเมนต์ที่บรรทุกให้กระจายสม่ำเสมอเต็มกระบะบรรทุก

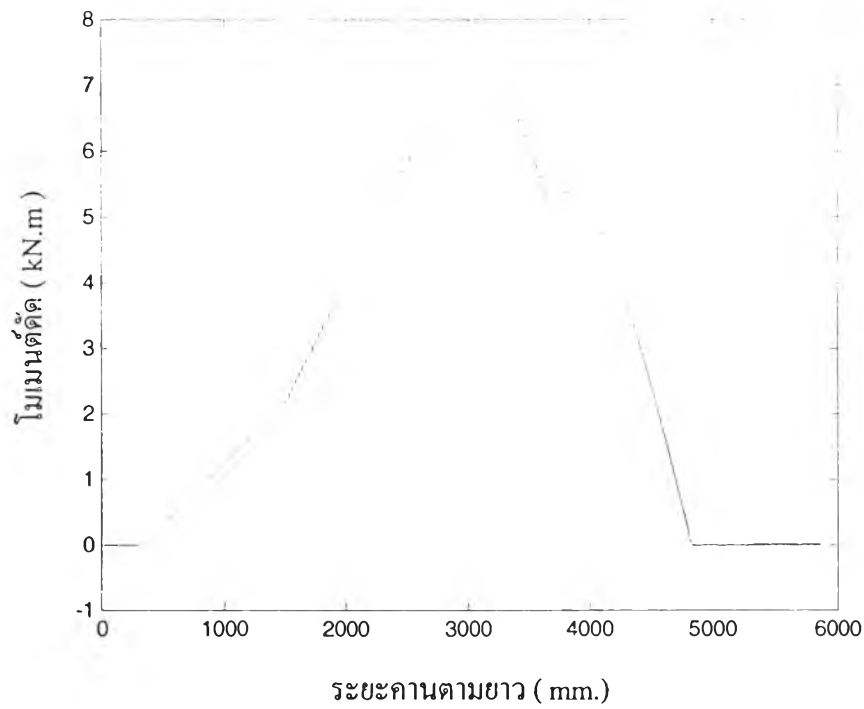
(2) การจัดวางถุงปูนซีเมนต์ที่บรรทุกให้เป็นกองรวมกัน โดยให้ด้านหน้าสุดของกองอยู่ห่างจากด้านหน้าของกระบะบรรทุกเป็นระยะ 140 เซนติเมตร

(3) การจัดวางถุงปูนซีเมนต์ที่บรรทุกให้เป็นกองรวมกัน โดยให้ด้านหน้าสุดของกองอยู่ห่างจากด้านหน้าของกระบะบรรทุกเป็นระยะ 180 เซนติเมตร

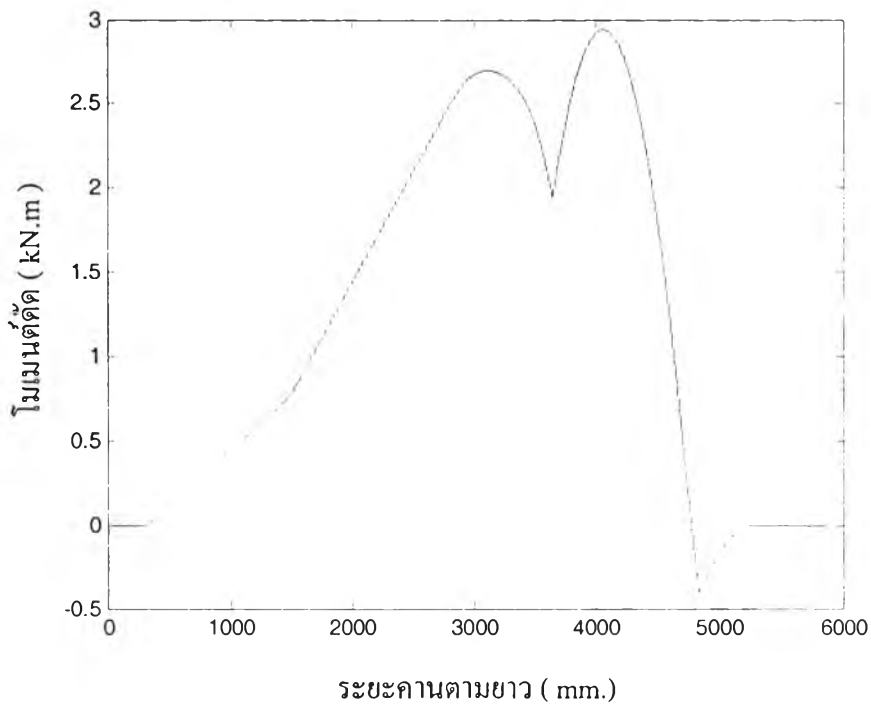
กราฟจะแสดงโมเมนต์ดัดที่คานตามยาวของโครงกรอบที่เกิดจากน้ำหนักของสิ่งที่บรรทุก ซึ่งจะไม่รวมน้ำหนักจากอุปกรณ์หรือน้ำหนักสิ่งของอื่น ๆ ใน 3 กรณี เช่นเดียวกับที่ทดสอบ เพื่อใช้เปรียบเทียบกับผลที่ได้จากการทดสอบทั้ง



รูปที่ ง.1 โมเมนต์ดัดที่คานตามยาวจากการวางถุงปูนให้กระจายตัวสม่ำเสมอเต็มกระบะบรรทุก



รูปที่ ง.2 โมเมนต์ดัดจากการคำนวณที่คานตามยาว จากการวางถุงปูนเป็นกองโดยให้ด้านหน้าสุดของกองอยู่ห่างจากด้านหน้าของกระบะที่บรรทุก 140 เซนติเมตร.



รูปที่ ง.3 โมเมนต์ดัดจากการคำนวณที่คานตามยาว จากการวางถุงปูนเป็นกองโดยให้ด้านหน้าสุดของกองอยู่ห่างจากด้านหน้าของกระบะที่บรรทุก 180 เซนติเมตร.

ภาคผนวก จ

โปรแกรมที่ใช้คำนวณหาโมเมนต์ดัดในโครงกรอบ

1. โปรแกรมที่ใช้หาโมเมนต์ดัดจากภาระกรณีที่ 1

โปรแกรมที่ใช้ในการคำนวณโมเมนต์ดัดจากภาระของน้ำหนักของอุปกรณ์ และสิ่งของที่บรรทุกจะแบ่งออกเป็น 3 โปรแกรมคือ

(1) โปรแกรมที่ใช้คำนวณโมเมนต์ดัดที่เกิดขึ้นจากภาระที่มาจากน้ำหนักของอุปกรณ์ และสิ่งของที่บรรทุกที่มีการบรรทุกเต็มกระบะที่บรรทุก โดยแรงจากน้ำหนักที่บรรทุกกระทำกับคานตามยาวของโครงกรอบเป็นจุด (Concentrated Load)

```
%=========================================================================
%Case 1 (Static load)
%This program computes bending moment in horizontal beam.
%=========================================================================
clc
clear all
close all
%Input Data ==============================================================
%Change input data if another model.
%=========================================================================
L=[130 1050 1340 1615 1920 2065 2110 2350 2515 2965 3445 3895 4265 4665 4965 5145 5545
5865];  %(mm.)
W=[400 300 200 211.76 112.5 423.53 7.5 55 423.53 437.64 437.64 385.88 362.36 414.12 15
414.12 338.83 150.59];  %(kg.)
n=18;     %Number of load.
L1=900;   %(mm.)
L2=3365;  %(mm.)
L3=1600;  %(mm.)
Lf1=575;  %(mm.)
Lf2=580;  %(mm.)
Lr1=614;  %(mm.)
Lr2=565;  %(mm.)
%=========================================================================
%calculate for reaction force.
% force direction right and up is positive.
% force direction left and down is negative.
%=========================================================================
% W = load for calculate in newton.
W=-(9.81*W);
% find Rr from summation moment at front wheel equal zero.
% Rf,Rr = reaction force on front and rear wheel.
Rr=-(sum(W.*(L-L1)))/L2
Rf=-(sum(W)+Rr)
% Rf1,Rf2 = reaction force on front leaf spring.
% Rr1,Rr2 = reaction force on rear leaf spring.
Rf1=(Lf2*Rf)/(Lf1+Lf2);
Rf2=Rf-Rf1
Rr1=(Lr2*Rr)/(Lr1+Lr2);
Rr2=Rr-Rr1
%=========================================================================
%length and load for calculate.
%=========================================================================
% a,b = length of front and rear support of front leaf spring.
% c,d = length of front and rear support of rear leaf spring.
a=L1-Lf1;
b=L1+Lf2;
c=L1+L2-Lr1;
d=L1+L2+Lr2;
%=========================================================================
```

```
%If length of reaction force equal lenght of load.
%=========================================================================
i=1;
for j=1:100;
       if L(i)==a;
            Rf1=W(i)+Rf1;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
       if L(i)==b;
            Rf2=W(i)+Rf2;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
       if L(i)==c;
            Rr1=W(i)+Rr1;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
       if L(i)==d;
            Rr2=W(i)+Rr2;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
    if i>=n;,break,end
    i=i+1;
end
% Sort length for find bending moment.
% A,B = length for find bending moment.
A=[L a b c d];,B=sort(A);
% w = load for calculate to find bending moment.
for i=1:n+4;
         for j=1:n;
             if B(i)==L(j);
                w(i)=W(j);
             end
         end
    if B(i)==a;
        w(i)=Rf1;
    end
    if B(i)==b;
        w(i)=Rf2;
    end
    if B(i)==c;
        w(i)=Rr1;
    end
    if B(i)==d;
        w(i)=Rr2;
    end
end
E=B;
F=B(1);
% length start to calculate at the first load.
B=B-B(1);
%=========================================================================
%calculate bending moment.
%=========================================================================
% x = length of horizontal chassis beam.
% m = bending moment.
% find m from equation m(n)=m(n-1)-[(x-L(n))*w(n)]
k=0;
for    i=1:100000;
       x(i)=k;
       m(i)=w(1)*x(i);
        for j=2:(n+4);
           if x(i)>B(j);
               m(i)=m(i)+(w(j)*(x(i)-B(j)));
           end
        end
   if x(i)>=L1+L2+L3-F;,break,end
   k=k+1;
end
% length previous first load.
```

```
k=0;
for j=1:10000;
    f(j)=k;
    h(j)=0;
    if f(j)>=(F-2),break,end
    k=k+1;
end
% combine length previous first load.
x=x+F;
x=[f x];
% find bending moment in one beam.
m=m/2;
m=[h m];  %(N.mm)
%change unit of bending moment.
m1=m/1000000;  %(kN.m)
%=========================================================================
%Plot length with bending moment.
%=========================================================================
plot(x,m1)
title('Bending moment Diagram for Case 1 ( Static load )')
xlabel('Length < mm.>')
ylabel('Bending moment < kN.m >')
legend('Bending moment on horizontal beam')
grid
axis('on')
%=========================================================================
```

(2) โปรแกรมที่ใช้คำนวณโมเมนต์ดัดที่เกิดขึ้นจากภาระที่มาจากน้ำหนักของอุปกรณ์ และสิ่งของที่บรรทุกที่มีการบรรทุกเต็มกระบะที่บรรทุก โดยแรงจากน้ำหนักที่บรรทุกกระทำกับคานตามยาวของโครงกรอบแบบสม่ำเสมอ (Distributed Load)

```
%=========================================================================
%Case 1 (Static load)
%This program computes bending moment in horizontal beam.
%Use for full part distributed load on chassis.
%=========================================================================
clc
clear all
close all
%Input Data ==============================================================
%Change input data if another model.
%=========================================================================
n=7;      %Number of load.
W=[400 300 200 112.5 7.5 55 15];        %(kg.)
L=[130 1050 1340 1920 2110 2350 4965];  %(mm.)
N=1;      %Number distributed load.
q=9.233;  %Distributed load (N/mm.)
Lh=[1615 5865];  %Length of distributed load.
L1=900;   %(mm.)
L2=3365;  %(mm.)
L3=1600;  %(mm.)
Lf1=575;  %(mm.)
Lf2=580;  %(mm.)
Lr1=614;  %(mm.)
Lr2=566;  %(mm.)
%=========================================================================
%calculate for reaction force.
% force direction right and up is positive.
% force direction left and down is negative.
%=========================================================================
% W = load for calculate in newton.
W=-(9.81*W);
% wq = distributed load for calculate in newton.
% Lq = length of distributed load for calculate in newton.
wq=-(Lh(2)-Lh(1))*q;
Lq=((Lh(2)-Lh(1))/2)+Lh(1);
% find Rr from summation moment at front wheel equal zero.
% Rf,Rr = reaction force on front and rear wheel.
Rr=-((sum(W.*(L-L1)))+(wq*(Lq-L1)))/L2
```

```
Rf=-((sum(W)+wq)+Rr)
% Rf1,Rf2 = reaction force on front leaf spring.
% Rr1,Rr2 = reaction force on rear leaf spring.
Rf1=(Lf2*Rf)/(Lf1+Lf2)
Rf2=Rf-Rf1
Rr1=(Lr2*Rr)/(Lr1+Lr2)
Rr2=Rr-Rr1
%=========================================================================
%length and load for calculate.
%=========================================================================
% a,b = length of front and rear support of front leaf spring.
% c,d = length of front and rear support of rear leaf spring.
a=L1-Lf1;
b=L1+Lf2;
c=L1+L2-Lr1;
d=L1+L2+Lr2;
%=========================================================================
%If length of reaction force equal lenght of load.
%=========================================================================
i=1;
for j=1:100;
       if L(i)==a;
            Rf1=W(i)+Rf1;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
       if L(i)==b;
            Rf2=W(i)+Rf2;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
       if L(i)==c;
            Rr1=W(i)+Rr1;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
       if L(i)==d;
            Rr2=W(i)+Rr2;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
    if i>=n;,break,end
    i=i+1;
end
% Sort length for find bending moment.
% A,B = length for find bending moment.
A=[L a b c d];,B=sort(A);
% w = load for calculate to find bending moment.
for i=1:n+4;
         for j=1:n;
             if B(i)==L(j);
                w(i)=W(j);
             end
         end
    if B(i)==a;
        w(i)=Rf1;
    end
    if B(i)==b;
        w(i)=Rf2;
    end
    if B(i)==c;
        w(i)=Rr1;
    end
    if B(i)==d;
        w(i)=Rr2;
    end
end
E=B;
F=B(1);
% length start to calculate at the first load.
Lh=Lh-F;
B=B-B(1);
%=========================================================================
```

```
%calculate bending moment.
%=========================================================================
% x = length of horizontal chassis beam.
% m = bending moment.
% find m from equation m(n)=m(n-1)-[(x-L(n))*w(n)]
k=0;
for i=1:100000;
    x(i)=k;
    m(i)=w(1)*x(i);
      for j=2:(n+4);
          if x(i)>B(j);
             m(i)=m(i)+(w(j)*(x(i)-B(j)));
          end
      end
      % include bending moment from distribution load.
      if x(i)>=Lh(1);
         m(i)=m(i)-(q*(x(i)-Lh(1))*(x(i)-Lh(1))/2);
      end
   if x(i)>=L1+L2+L3-F;,break,end
   k=k+1;
end
% length previous first load.
k=0;
for j=1:10000;
    f(j)=k;
    h(j)=0;
    if f(j)>=(F-2),break,end
    k=k+1;
end
% combine length previous first load.
x=x+F;
x=[f x];
% find bending moment in one beam.
m=m/2;
m=[h m];        %(N.mm)
%change unit of bending moment.
m1=m/1000000;  %(kN.m)
%=========================================================================
%Plot length with bending moment.
%=========================================================================
plot(x,m1)
title('Bending moment Diagram for Case 1 ( Static load )')
xlabel('Length < mm.>')
ylabel('Bending moment < kN.m >')
legend('Bending moment on horizontal beam')
grid
axis('on')
%=========================================================================
```

(3) โปรแกรมที่ใช้คำนวณโมเมนต์ดัดที่เกิดขึ้นจากภาระที่มาจากน้ำหนักของอุปกรณ์ และสิ่งของที่บรรทุกที่มีการบรรทุกบางส่วนของกระบะที่บรรทุก โดยแรงจากน้ำหนักที่บรรทุกกระทำกับคานตามยาวของโครงกรอบแบบสม่ำเสมอ (Distributed Load)

```
%=========================================================================
%Case 1 (Static load)
%This program computes bending moment in horizontal beam.
%Use for some part distributed load on chassis.
%=========================================================================
clc
clear all
close all
%Input Data ==============================================================
%Change input data if another model.
%=========================================================================
n=7;       %Number concentrated load.
W=[400 300 200 112.5 7.5 55 15];         %(kg.)
L=[130 1050 1340 1920 2110 2350 4965];   %(mm.)
N=3;       %Number distributed load.
q=[7.848 23.544 7.848];      %Distributed load (N/mm.)
```

```
Lh=[2790 3415 4665 5290];   %Length of distributed load.
L1=900;   %(mm.)
L2=3365;  %(mm.)
L3=1600;  %(mm.)
Lf1=575;  %(mm.)
Lf2=580;  %(mm.)
Lr1=614;  %(mm.)
Lr2=566;  %(mm.)
%=========================================================================
%calculate for reaction force.
% force direction right and up is positive.
% force direction left and down is negative.
%=========================================================================
% W = concentrated load for calculate in newton.
W=-(9.81*W);
% wq = distributed load for calculate in newton.
% Lq = length of distributed load for calculate in newton.
for i=1:N;
    wq(i)=-(Lh(i+1)-Lh(i))*q(i);
    Lq(i)=((Lh(i+1)-Lh(i))/2)+Lh(i);
end
% find Rr from summation moment at front wheel equal zero.
% Rf,Rr = reaction force on front and rear wheel.
Rr=-((sum(W.*(L-L1)))+(sum((Lq-L1).*wq)))/L2
Rf=-((sum(W)+sum(wq))+Rr)
% Rf1,Rf2 = reaction force on front leaf spring.
% Rr1,Rr2 = reaction force on rear leaf spring.
Rf1=(Lf2*Rf)/(Lf1+Lf2)
Rf2=Rf-Rf1
Rr1=(Lr2*Rr)/(Lr1+Lr2)
Rr2=Rr-Rr1
%=========================================================================
%length and load for calculate.
%=========================================================================
% a,b = length of front and rear support of front leaf spring.
% c,d = length of front and rear support of rear leaf spring.
a=L1-Lf1;
b=L1+Lf2;
c=L1+L2-Lr1;
d=L1+L2+Lr2;
%=========================================================================
%If length of reaction force equal lenght of load.
%=========================================================================
i=1;
for j=1:100;
       if L(i)==a;
            Rf1=W(i)+Rf1;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
       if L(i)==b;
            Rf2=W(i)+Rf2;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
       if L(i)==c;
            Rr1=W(i)+Rr1;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
       if L(i)==d;
            Rr2=W(i)+Rr2;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
    if i>=n;,break,end
    i=i+1;
end
% Sort length for find bending moment.
% A,B = length for find bending moment.
A=[L a b c d];,B=sort(A);
% w = load for calculate to find bending moment.
for i=1:n+4;
```

```
        for j=1:n;
            if B(i)==L(j);
               w(i)=W(j);
            end
        end
    if B(i)==a;
        w(i)=Rf1;
    end
    if B(i)==b;
        w(i)=Rf2;
    end
    if B(i)==c;
        w(i)=Rr1;
    end
    if B(i)==d;
        w(i)=Rr2;
    end
end
E=B;
F=B(1);
% length start to calculate at the first load.
Lh=Lh-B(1);
B=B-B(1);
%=========================================================================
%calculate bending moment.
%=========================================================================
% x = length of horizontal chassis beam.
% m = bending moment.
% find m from equation m(n)=m(n-1)-[(x-L(n))*w(n)]
k=0;
for i=1:100000;
    x(i)=k;
    m(i)=w(1)*x(i);
      for j=2:(n+4);
          if x(i)>B(j);
             m(i)=m(i)+(w(j)*(x(i)-B(j)));
          end
      end
      % include bending moment from distribution load.
      if x(i)>=Lh(1);
          m(i)=m(i)-(q(1)*(x(i)-Lh(1))*(x(i)-Lh(1))/2);
      end
      if x(i)>=Lh(2);
          m(i)=m(i)+(q(1)*(x(i)-Lh(2))*(x(i)-Lh(2))/2)-(q(2)*(x(i)-Lh(2))*(x(i)-
Lh(2))/2);
      end
      if x(i)>=Lh(3);
          m(i)=m(i)+(q(2)*(x(i)-Lh(3))*(x(i)-Lh(3))/2)-(q(3)*(x(i)-Lh(3))*(x(i)-
Lh(3))/2);
      end
      if x(i)>=Lh(4);
          m(i)=m(i)+(q(3)*(x(i)-Lh(4))*(x(i)-Lh(4))/2);
      end
   if x(i)>=L1+L2+L3-F;,break,end
   k=k+1;
end
% length previous first load.
k=0;
for j=1:10000;
    f(j)=k;
    h(j)=0;
    if f(j)>=(F-2),break,end
    k=k+1;
end
% combine length previous first load.
x=x+F;
x=[f x];
% find bending moment in one beam.
m=m/2;
m=[h m];        %(N.mm)
%change unit of bending moment.
m1=m/1000000;  %(kN.m)
%=========================================================================
%Plot length with bending moment.
%=========================================================================
plot(x,m1)
title('Bending moment Diagram for Case 1 ( Static load )')
```

```
xlabel('Length < mm.>')
ylabel('Bending moment < kN.m >')
legend('Bending moment on horizontal beam')
grid
axis('on')
%=========================================================================
```

2. โปรแกรมที่ใช้หาโมเมนต์ดัดจากภาระกรณีที่ 2

โปรแกรมที่ใช้ในการคำนวณโมเมนต์ดัดจากภาระกรณีที่ 2 แบ่งออกเป็น 2 โปรแกรมคือ

2.1 โปรแกรมที่ใช้หาโมเมนต์ดัดจากภาระกรณีที่ 2a (การเบรก)

```
%=========================================================================
%Case 2a (Brake ,a=0.8g)
%This program computes bending moment in horizontal beam.
%Calculate only cab and carry weight because center of gravity is high of neutral axis
.
%=========================================================================
clc
clear all
close all
%Input Data ==============================================================
%Change input data if another model.
%=========================================================================
mc=600;   % cab weight(kg.)
mf=2000;  % weight on front axle.(kg.)
mr=4000;  % weight on rear axle.(kg.)
mlf=200;  % weight of front axle.(kg.)
mlr=300;  % weight of rear axle.(kg.)
q=0.9412; % distributed load.(kg/mm.)
hi=700;   % equal chassis wide.(mm.)
CGc=500;  %(mm.)assum from real dimension.
Lx1=130;  %(mm.)
Lx2=1340; %(mm.)
Lx3=1615; %(mm.)
Lx4=5865; %(mm.)
L1=900;   %(mm.)
L2=3365;  %(mm.)
L3=1600;  %(mm.)
Lf1=575;  %(mm.)
Lf2=580;  %(mm.)
Lr1=614;  %(mm.)
Lr2=565;  %(mm.)
hff=360;  %(mm.)
hfr=500;  %(mm.)
ef=195;   %(mm.)
er=55;    %(mm.)
rf=370;   %(mm.)
rr=370;   %(mm.)
%=========================================================================
%calculate for reaction force.
%=========================================================================
% force direction right and up is positive.
% force direction left and down is negative.
% delta.f = force at front and rear wheel from brake.
delta.f=(mf+mr)*0.8*9.81*(hi+hff+ef)/L2;
% Bf,Br = friction force on front and rear wheel.
% friction coefficient = 0.8
Bf=0.8*((9.81*mf)+delta.f);
Br=0.8*((9.81*mr)-delta.f);
% mlfa,mlra = inertia force of front and rear wheel.
% a=0.8g
mlfa=-(0.8*9.81*mlf);
mlra=-(0.8*9.81*mlr);
% tf = length of center of front wheel to front support of front leaf spring.
% tr = length of center of rear wheel to front support of rear leaf spring.
tf=hff-rf;
tr=hfr-rr;
```

```
% fAA,fBB = couple force on support of front and rear leaf spring.
fAA=((Bf*hff)+(mlfa*tf))/(Lf1+Lf2);
fBB=((Br*hfr)+(mlra*tr))/(Lr1+Lr2);
% ff,fr = horizontal force on support of front and rear leaf spring.
ff=Bf+mlfa;
fr=Br+mlra;
% L = length of load.
L=[Lx1 Lx2 Lx3 Lx4];
% fA,fB = couple force on front and rear support of cab and pick-up truck.
fA=(0.8*9.81*mc*CGc)/(L(2)-L(1));
fB=(0.8*9.81*q*hi);
% bmf,bmr = bending moment on front support of front and rear leaf spring.
bmf=(ff*ef);
bmr=(fr*er);
% s = summation of moment at front wheel.
% find reaction force on front and rear wheel.
s=(fAA*(Lf1+Lf2))+(fA*(L1-L(1)))+(fA*(L(2)-L1))+(fB*(L(4)-L1))+(fBB*(L2+Lr2))-
(fB*(L(3)-L1))-(fBB*(L2-Lr1))+bmf+bmr;
% deltaRf,deltaRr = reaction force on front and rear wheel.
deltaRr=-s/L2
deltaRf=-deltaRr
% Rf1,Rf2 = reaction force on front leaf spring.
% Rr1,Rr2 = reaction force on rear leaf spring.
b1=Lf1+Lf2;
c1=Lf2*deltaRf;
Rf1=c1/b1
Rf2=deltaRf-Rf1
b2=Lr1+Lr2;
c2=Lr2*deltaRr;
Rr1=c2/b2
Rr2=deltaRr-Rr1
%=========================================================================
%length and load for calculate.
%=========================================================================
% a,b = length of front and rear support of front leaf spring.
% c,d = length of front and rear support of rear leaf spring.
a=L1-Lf1;
b=L1+Lf2;
c=L1+L2-Lr1;
d=L1+L2+Lr2;
% e,f = equilibrium force at front and rear support of front leaf spring.
% g,h = equilibrium force at front and rear support of rear leaf spring.
e=Rf1-fAA;
f=Rf2+fAA;
g=Rr1-fBB;
h=Rr2+fBB;
%=========================================================================
%If length of reaction force equal lenght of load.
%=========================================================================
% W = force from brake on chassis.
W=[-fA fA -fB fB];
n1=4;
i=1;
for j=1:100;
       if L(i)==a;
              e=e-fA;
           L(i)=[];
           W(i)=[];
             n1=n1-1;
       end
       if L(i)==b;
              f=f+fA;
           L(i)=[];
           W(i)=[];
             n1=n1-1;
       end
       if L(i)==c;
              g=g-fB;
           L(i)=[];
           W(i)=[];
             n1=n1-1;
       end
       if L(i)==d;
              h=h+fB;
           L(i)=[];
           W(i)=[];
             n1=n1-1;
```

```
        end
            if i>=n1;,break,end
    i=i+1;
end
% S,T = length for find bending moment.
S=[L a b c d];,T=sort(S);
% w = load for calculate.
n=n1+4;
for i=1:n;
    for j=1:n1;
        if T(i)==L(j);
           w(i)=W(j);
        end
    end
            if T(i)==a;
               w(i)=e;
            end
            if T(i)==b;
               w(i)=f;
            end
            if T(i)==c;
               w(i)=g;
            end
            if T(i)==d;
               w(i)=h;
            end
end
E=T;
F=T(1);
% length start to calculate at the first load.
T=T-T(1);
%=========================================================================
%calculate bending moment.
%=========================================================================
% x = length of horizontal chassis beam.
% m = bending moment.
% find m from equation m(n)=m(n-1)-[(x-L(n))*w(n)]
k=0;
for    j=1:100000;
       x(j)=k;
       m(j)=w(1)*x(j);
        for p=2:n;
           if x(j)>T(p);
              m(j)=m(j)+(w(p)*(x(j)-T(p)));
           end
        end
   if x(j)>=T(n);,break,end
   k=k+1;
end
% combine m with bending moment on front support of front and rear leaf spring.
k=0;
for j=1:100000;
    x(j)=k;
    if x(j)>a-F;
       m(j)=m(j)-bmf;
       if x(j)>c-F;
          m(j)=m(j)-bmr;
       end
    end
    if x(j)>=T(n);,break,end
    k=k+1;
end
% length previous first load.
k=0;
for j=1:10000;
    f(j)=k;
    h(j)=0;
    if f(j)>=(F-2),break,end
    k=k+1;
end
% combine length previous first load.
x=x+F;
x=[f x];
% find bending moment in one beam.
m=m/2;
m=[h m];        %(N.mm)
% change unit of bending moment.
```

```
ml=m/1000000;  %(kN.m)
%=========================================================================
%Plot length with bending moment.
%=========================================================================
plot(x,ml)
title('Bending moment Diagram for Case 2a ( Brake )')
xlabel('Length < mm.>')
ylabel('Bending moment < kN.m >')
legend('Bending moment on horizontal beam')
grid
axis('on')
%=========================================================================
```

2.2 โปรแกรมที่ใช้หาโมเมนต์ดัดจากภาระกรณีที่ 2b (การเร่งออกตัว)

```
%=========================================================================
%Case 2b (Acceleration ,F=l*<weight on wheel drive>)
%This program computes bending moment in horizontal beam.
%Calculate only cab and container weight because center of gravity is high of neutral
axis .
%=========================================================================
clc
clear all
close all
%Input Data ==============================================================
%Change input data if another model.
%=========================================================================
mc=600;   % cab weight(kg.)
mf=2000;  % weight on front axle.(kg.)
mr=4000;  % weight on rear axle.(kg.)
mlf=200;  % weight of front axle.(kg.)
mlr=300;  % weight of rear axle.(kg.)
q=0.9412; % distributed load.(kg/mm.)
hi=700;   % equal chassis wide.(mm.)
CGc=500;  %(mm.)assum from real dimension.
Lx1=130;  %(mm.)
Lx2=1340; %(mm.)
Lx3=1615; %(mm.)
Lx4=5865; %(mm.)
L1=900;   %(mm.)
L2=3365;  %(mm.)
L3=1600;  %(mm.)
Lf1=575;  %(mm.)
Lf2=580;  %(mm.)
Lr1=614;  %(mm.)
Lr2=565;  %(mm.)
hff=360;  %(mm.)
hfr=500;  %(mm.)
ef=195;   %(mm.)
er=55;    %(mm.)
rf=370;   %(mm.)
rr=370;   %(mm.)
%=========================================================================
%calculate for reaction force.
%=========================================================================
% force direction right and up is positive.
% force direction left and down is negative.
% Force = l*(weight on wheel drive)
% fd = maximum drive force.
fd=-(l*9.81*mr);
% ac = acceleration of car.
ac=(-fd)/(mf+mr);
% mlfa,mlra = inertia force of front and rear wheel.
mlfa=mlf*ac;
mlra=mlr*ac;
% tf = length of center of front wheel to front support of front leaf spring.
% tr = length of center of rear wheel to front support of rear leaf spring.
tf=(hff-rf);
tr=(hfr-rr);
% fAA,fBB = couple force on support of front and rear leaf spring.
fAA=-(mlfa*tf)/(Lf1+Lf2);
```

```
fBB=-((mlra*tr)+(fd*hfr))/(Lr1+Lr2);;
% L = length of load.
L=[Lx1 Lx2 Lx3 Lx4];
% fA,fB = couple force at front and rear support of cab and pick-up truck.
fA=(ac*mc*CGc)/(L(2)-L(1));
fB=(ac*q*hi);
% bmf,bmr = bending moment on front support of front and rear leaf spring.
bmf=(mlfa*ef);
bmr=(mlra+fd)*er;
% s = summation of moment to find reaction force on front and rear wheel.
s=(fAA*(Lf1+Lf2))+(fA*(L1-L(1)))+(fA*(L(2)-L1))+(fB*(L(4)-L1))+(fBB*(L2+Lr2))-
(fB*(L(3)-L1))-(fBB*(L2-Lr1))-bmf-bmr;
% deltaRf,deltaRr = reaction force on front and rear wheel.
deltaRr=s/L2
deltaRf=-deltaRr
% Rf1,Rf2 = reaction force on front leaf spring.
% Rr1,Rr2 = reaction force on rear leaf spring.
b1=Lf1+Lf2;
c1=Lf2*deltaRf;
Rf1=c1/b1
Rf2=deltaRf-Rf1
b2=Lr1+Lr2;
c2=Lr2*deltaRr;
Rr1=c2/b2
Rr2=deltaRr-Rr1
%=============================================================================
%length and load for calculate..
%=============================================================================
% a,b = length of front and rear support of front leaf spring.
% c,d = length of front and rear support of rear leaf spring.
a=L1-Lf1;
b=L1+Lf2;
c=L1+L2-Lr1;
d=L1+L2+Lr2;
% e,f = equilibrium force on front and rear support of front leaf spring.
% g,h = equilibrium force on front and rear support of rear leaf spring.
e=Rf1+fAA;
f=Rf2-fAA;
g=Rr1+fBB;
h=Rr2-fBB;
%=============================================================================
%If length of reaction force equal lenght of load.
%=============================================================================
% W = force from brake on chassis.
W=[fA -fA fB -fB];
n1=4;
i=1;
for j=1:100;
       if L(i)==a;
              e=e+fA;
           L(i)=[];
           W(i)=[];
             n1=n1-1;
       end
       if L(i)==b;
              f=f-fA;
           L(i)=[];
           W(i)=[];
             n1=n1-1;
       end
       if L(i)==c;
              g=g+fB;
           L(i)=[];
           W(i)=[];
             n1=n1-1;
       end
       if L(i)==d;
              h=h-fB;
           L(i)=[];
           W(i)=[];
             n1=n1-1;
       end
           if i>=n1;,break,end
    i=i+1;
end
% S,T = length for find bending moment.
S=[L a b c d];,T=sort(S);
```

```
% w = load for calculate.
n=n1+4;
for i=1:n;
    for j=1:n1;
        if T(i)==L(j);
           w(i)=W(j);
        end
    end
            if T(i)==a;
               w(i)=e;
            end
            if T(i)==b;
               w(i)=f;
            end
            if T(i)==c;
               w(i)=g;
            end
            if T(i)==d;
               w(i)=h;
            end
end
E=T;
F=T(1);
% length start to calculate at the first load.
T=T-T(1);
%=========================================================================
%calculate bending moment.
%=========================================================================
% x = length of horizontal chassis beam.
% m = bending moment.
% find m from equation m(n)=m(n-1)-[(x-L(n))*w(n)]k=0;
k=0;
for    j=1:100000;
       x(j)=k;
       m(j)=w(1)*x(j);
        for p=2:n;
           if x(j)>T(p);
              m(j)=m(j)+(w(p)*(x(j)-T(p)));
           end
        end
   if x(j)>=T(n);,break,end
   k=k+1;
end
% combine m with bending moment on front support of front and rear leaf spring.
k=0;
for j=1:100000;
    x(j)=k;
    if x(j)>a-F;
       m(j)=m(j)-bmf;
       if x(j)>c-F;
          m(j)=m(j)-bmr;
       end
    end
    if x(j)>=T(n);,break,end
    k=k+1;
end
% length previous first load.
k=0;
for j=1:10000;
    f(j)=k;
    h(j)=0;
    if f(j)>=(F-2),break,end
    k=k+1;
end
% combine length previous first load.
x=x+F;
x=[f x];
% find bending moment in one beam.
m=m/2;
m=[h m];          %(N.mm)
% change unit of bending moment.
m1=m/1000000;     %(kN.m)
%=========================================================================
%Plot length with bending moment.
%=========================================================================
plot(x,m1)
title('Bending moment Diagram for Case 2b ( Acceleration )')
```

```
xlabel('Length < mm.>')
ylabel('Bending moment < kN.m >')
legend('Bending moment on horizontal beam')
grid
axis('on')
%=========================================================================
```

3. โปรแกรมที่ใช้หาโมเมนต์ดัดจากภาระกรณีที่ 3

โปรแกรมที่ใช้ในการคำนวณโมเมนต์ดัดจากภาระกรณีที่ 3 แบ่งออกเป็น 2 โปรแกรมคือ

3.1 โปรแกรมที่ใช้หาโมเมนต์ดัดจากภาระกรณีที่ 3 การแรงกระทำในแนวดิ่ง

```
%=========================================================================
%case 3a (On the curve road)
%Effect of vertical load a=0.5g
%This program computes bending moment in horizontal beam.
%Calculate only cab and carry weight because center of gravity is high of neutral axis
.
%=========================================================================
clc
clear all
close all
%Input Data ==============================================================
%Change input data if another model.
%=========================================================================
L=[130 1340 1615 2065 2515 2965 3445 3895 4265 4665 5145 5545 5865];  %(mm.)
W=[400 200 211.76 423.53 423.53 437.64 437.64 385.88 362.36 414.12 414.12 338.83
150.59];  %(kg.)
hi=700;   % equal chassis wide.(mm.)
CGc=500;  % assum from real dimension.(mm.)
L1=900;   %(mm.)
L2=3365;  %(mm.)
L3=1600;  %(mm.)
Lf1=575;  %(mm.)
Lf2=580;  %(mm.)
Lr1=614;  %(mm.)
Lr2=565;  %(mm.)
%=========================================================================
%calculate for reaction force.
% force direction right and up is positive.
% force direction left and down is negative.
%=========================================================================
[nn1,ind]=max(L);
n=ind;
% W = load for calculate in newton.
% find W from 0.5mg
% W(1),W(2) depend on CGc and hi of cab.
W(1)=-0.5*9.81*W(1)*CGc/hi;
W(2)=-0.5*9.81*W(2)*CGc/hi;
for i=3:n;
W(i)=-0.5*9.81*W(i);
end
% find deltaRr from summation moment at front wheel equal zero.
% deltaRf,deltaRr = reaction force on front and rear wheel.
deltaRr=-(sum(W.*(L-L1)))/L2
deltaRf=-(sum(W)+deltaRr)
% Rf1,Rf2 = reaction force on front leaf spring.
% Rr1,Rr2 = reaction force on rear leaf spring.
b1=Lf1+Lf2;
c1=Lf2*deltaRf;
Rf1=c1/b1
Rf2=deltaRf-Rf1
b2=Lr1+Lr2;
c2=Lr2*deltaRr;
Rr1=c2/b2
Rr2=deltaRr-Rr1
%=========================================================================
%length and load for calculate.
%=========================================================================
```

```
% a,b = length of front and rear support of front leaf spring.
% c,d = length of front and rear support of rear leaf spring.
a=L1-Lf1;
b=L1+Lf2;
c=L1+L2-Lr1;
d=L1+L2+Lr2;
%=========================================================================
%If length of reaction force equal lenght of load.
%=========================================================================
i=1;
for j=1:100;
       if L(i)==a;
            Rf1=W(i)+Rf1;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
       if L(i)==b;
            Rf2=W(i)+Rf2;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
       if L(i)==c;
            Rr1=W(i)+Rr1;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
       if L(i)==d;
            Rr2=W(i)+Rr2;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
    if i>=n;,break,end
    i=i+1;
end
% Sort length for find bending moment.
% A,B = length for find bending moment.
A=[L a b c d];,B=sort(A);
% w = load for calculate to find bending moment.
for i=1:n+4;
         for j=1:n;
             if B(i)==L(j);
                w(i)=W(j);
             end
         end
    if B(i)==a;
        w(i)=Rf1;
    end
    if B(i)==b;
        w(i)=Rf2;
    end
    if B(i)==c;
        w(i)=Rr1;
    end
    if B(i)==d;
        w(i)=Rr2;
    end
end
E=B;
F=B(1);
% length start to calculate at the first load.
B=B-B(1);
%=========================================================================
%calculate bending moment.
%=========================================================================
% x = length of horizontal chassis beam.
% m = bending moment.
% find m from equation m(n)=m(n-1)-[(x-L(n))*w(n)]
k=0;
for     i=1:100000;
       x(i)=k;
       m(i)=w(1)*x(i);
        for j=2:(n+4);
           if x(i)>B(j);
```

```
                m(i)=m(i)+(w(j)*(x(i)-B(j)));
            end
        end
   if x(i)>=B(n+4);,break,end
   k=k+1;
end
% length previous first load.
k=0;
for j=1:10000;
    f(j)=k;
    h(j)=0;
    if f(j)>=(F-2),break,end
    k=k+1;
end
% combine length previous first load.
x=x+F;
x=[f x];
% find bending moment in one beam.
m=m/2;
m=[h m];  %(N.mm)
%change unit of bending moment.
ml=m/1000000;  %(kN.m)
%=========================================================================
%Plot length with bending moment.
%=========================================================================
plot(x,ml)
title('Bending moment Diagram for Case 3a ( On the curve road, Effect of vertical load
)')
xlabel('Length < mm.>')
ylabel('Bending moment < kN.m >')
legend('Bending moment on longitudinal beam')
grid
axis('on')
%=========================================================================
```

3.2 โปรแกรมที่ใช้หาโมเมนต์ดัดจากภาระกรณีที่ 3 การแรงกระทำในแนวระดับ

```
%=========================================================================
%Case 3b (Load on chassis plane,a=0.5g)
%This program computes bending moment in the plane chassis.
%Calculate only cab and carry weight because center of gravity is high of neutral axis
.
%=========================================================================
clc
clear all
close all
%Input Data ==============================================================
%Change input data if another model.
%=========================================================================
L=[130 1340 1615 2065 2515 2965 3445 3895 4265 4665 5145 5545];  %(mm.)
W=[400 200 211.76 423.53 423.53 437.64 437.64 385.88 362.36 414.12 414.12 489.42];
%(kg.)
n=12;     %number of load.
Ic=[1 1 1 1 1 1 1];   %moment of inertia in each cross beam.
n11=7;    %number of cross chassis beam.
l=[417 1502 802 910 1332 622];  %(mm.)
bb=700;   %chassis wide.(mm.)
CGc=500;  %assum from real dimension.(mm.)
L1=900;   %(mm.)
L2=3365;  %(mm.)
L3=1600;  %(mm.)
Lf1=575;  %(mm.)
Lf2=580;  %(mm.)
Lr1=614;  %(mm.)
Lr2=565;  %(mm.)
%=========================================================================
%calculate reaction force.
%calculate only real positive integers length in mm.
%=========================================================================
% force direction right and up is positive.
% force direction left and down is negative.
```

```
% W = load for calculate in newton.
for i=1:n;
W(i)=-0.5*9.81*W(i);
end
% find Rr from summation moment at front wheel equal zero.
% Rf,Rr = reaction force on front and rear wheel.
Rr=-(sum(W.*(L-L1)))/L2
Rf=-(sum(W)+Rr)
% Rf1,Rf2 = reaction force on front leaf spring.
% Rr1,Rr2 = reaction force on rear leaf spring.
Rf1=(Lf2*Rf)/(Lf1+Lf2)
Rf2=Rf-Rf1
Rr1=(Lr2*Rr)/(Lr1+Lr2)
Rr2=Rr-Rr1
%=========================================================================
%length and load for calculate.
%=========================================================================
% a,b = length of front and rear support of front leaf spring.
% c,d = length of front and rear support of rear leaf spring.
a=L1-Lf1;
b=L1+Lf2;
c=L1+L2-Lr1;
d=L1+L2+Lr2;
i=1;
for j=1:100;
       if L(i)==a;
            Rf1=W(i)+Rf1;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
       if L(i)==b;
            Rf2=W(i)+Rf2;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
       if L(i)==c;
            Rr1=W(i)+Rr1;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
       if L(i)==d;
            Rr2=W(i)+Rr2;
           L(i)=[];
           W(i)=[];
              n=n-1;
       end
    if i>=n;,break,end
    i=i+1;
end
% Sort length for find bending moment.
% A,B = length for find bending moment.
A=[L a b c d];,B=sort(A);
% w = load for calculate to find bending moment.
for i=1:n+4;
         for j=1:n;
             if B(i)==L(j);
                w(i)=W(j);
             end
         end
    if B(i)==a;
        w(i)=Rf1;
    end
    if B(i)==b;
        w(i)=Rf2;
    end
    if B(i)==c;
        w(i)=Rr1;
    end
    if B(i)==d;
        w(i)=Rr2;
    end
end
%=========================================================================
%calculation internal force form external force.
```

```
%Normal force in cross chsssis beam is 0. Because is easy to create program.
%=========================================================================
% device w for calculate.
w=w/2;
%=========================================================================
% av = internal force on vertical plane.
%=========================================================================
% Sl = cumulate l.
Sl=cumsum(l);
for k=l:(nll-l);
    for i=l:n+4;
          if B(i)<Sl(k);
             qv(i)=w(i);
          end
    end
    av(k)=-sum(qv);
end
%=========================================================================
% ah = internal force on horizontal plane.
%=========================================================================
% aaa = summation moment of external force.
%first loop.
for k=l;
   for i=l:n+4;
          if B(i)<Sl(k);
             qh(i)=(w(i)*B(i));
          end
          aaa(k)=sum(qh);
   end
   ah(k)=-(aaa(k)+(l(k)*av(k)))/(bb/2);
end
%next loop.
for k=2:(nll-l);
   for i=l:n+4;
          if B(i)<Sl(k);
              if  B(i)>=Sl(k-l);
                  qh(i)=(w(i)*(B(i)-Sl(k-l)));
                 aaa(k)=sum(qh);
             end
          end
   end
   for j=l:k-l;
       aaa(k)=aaa(k)-aaa(k-j);
   end
   ah(k)=-(aaa(k)+(l(k)*av(k)))/(bb/2);
end
%=========================================================================
%calculate Mo(bending moment) from external force.
%=========================================================================
%Find Mo from external force.
% mxl = bending moment from external force.
for i=l:n+4;
    %case 1.
    if B(i)<=Sl(1)
       k=0;
       for  j=l:1000000;
            x(j)=k;
            mxl(i,j)=-w(i)*(B(i)-k);
            if x(j)>=B(i)
               mxl(i,j)=0;
               if x(j)>=Sl(nll-l);,break,end
            end
            k=k+l;
       end
    end
    %case 2.
    if B(i)>Sl(1);
       for q=2:(nll-l);
         if B(i)>=Sl(q-l);
           k=0;
           kl=0;
           for j=l:1000000;
               x(j)=k;
               mxl(i,j)=0;
               if x(j)>=Sl(q-l);
                  mxl(i,j)=-w(i)*((B(i)-Sl(q-l))-kl);
                  kl=kl+l;
```

```
                end
                if x(j)>=B(i);
                   mx1(i,j)=0;
                end
                k=k+1;
                if x(j)>=S1(n11-1);,break,end
            end
          end
        end
    end
end
%=============================================================================
% mx10 = add one column in mx1 for find mx1new.
%=============================================================================
mx10=[sum(mx1) 0];
% mx1new = new bending moment from mx1.
k=1;
for j=1:sum(1)+n11;
    mx1new(j)=mx10(k);
    for q=1:n11-1;
        if j==S1(q)+q;
           k=k-1;
           mx1new(j)=mx10(k);
        end
    end
    k=k+1;
end
mx1new=mx1new/1000;        % transform unit to N.m
%=============================================================================
%calculate Mo from av(vertical internal force).
%=============================================================================
% mx2 = bending moment from vertical internal force.
%first loop.
for i=1;
    k=0;
    for  j=1:1000000;
         x(j)=k;
         mx2(i,j)=-(av(i)*(S1(i)-k));
         if x(j)>S1(i);
            mx2(i,j)=0;
         end
         if x(j)>=S1(n11-1);,break,end
         k=k+1;
    end
end
%next loop.
for i=2:n11-2;
    k=0;
    for  j=1:1000000;
         x(j)=k;
         mx2(i,j)=0;
         if x(j)>=S1(i-1);
            mx2(i,j)=-(av(i)*(S1(i)-k));
         end
         if x(j)>S1(i);
            mx2(i,j)=0;
         end
         if x(j)>=S1(n11-1);,break,end
         k=k+1;
    end
end
%end loop.
for i=n11-1;
    k=0;
    for  j=1:1000000;
         x(j)=k;
         mx2(i,j)=0;
         if x(j)>=S1(i-1);
            mx2(i,j)=-(av(i)*(S1(i)-k));
         end
         if x(j)>=S1(n11-1);,break,end
         k=k+1;
    end
end
%=============================================================================
% mx20 = add one column in mx2 for find mx2new.
%=============================================================================
```

```
mx20=[sum(mx2) 0];
% mx2new = new bending moment from mx2.
k=1;
for j=1:sum(l)+nll;
    mx2new(j)=mx20(k);
    for q=1:nll-1;
        if j==Sl(q)+q;
           k=k-1;
           mx2new(j)=0;
        end
    end
    k=k+1;
end
mx2new=mx2new/1000;          % transform unit to N.m
%=============================================================================
% Mox = bending moment from external force in horizontal beam.
%=============================================================================
Mox=mx1new+mx2new;           %(N.m)
%=============================================================================
% x = length in x-axle for find bending moment.
% y = length in y-axle for find bending moment.
x=[x Sl];
x=sort(x);
y=[0:bb];
%=============================================================================
%Find Mo from ah(internal force).
%=============================================================================
% Moy = bending moment from external force in cross beam.
for  q=1:nll;
     for j=1:bb+1;
         if q<=(nll-1);
            Moy(q,j)=ah(q)*((bb/2)-y(j));
         end
         if q==nll;
            Moy(q,j)=0;
         end
     end
end
Moy=Moy/1000;                % transform unit to N.m
%=============================================================================
%calculate Mn from assume Xn=1 N.m
%Mn in horizontal beam.
%=============================================================================
% Mnu = bending moment(Mn) in upper beam.
% Mnl = bending moment(Mn) in lower beam.
%calculate M1,M2 (Horizontal beam)
for i=1;
    for j=1:sum(l)+nll;
        Mnu((i*2)-1,j)=((0.5/l(i))*(Sl(i)-x(j)))-1;
        Mnl((i*2)-1,j)=-(0.5/l(i))*(Sl(i)-x(j));
        Mnu((i*2),j)=-(0.5/l(i))*(Sl(i)-x(j));
        Mnl((i*2),j)=((0.5/l(i))*(Sl(i)-x(j)))-1;
        if j>Sl(i)+i;
           Mnu((i*2)-1,j)=(-0.5/l(i+1))*(Sl(i+1)-x(j));
           Mnl((i*2)-1,j)=(0.5/l(i+1))*(Sl(i+1)-x(j));
           Mnu((i*2),j)=(0.5/l(i+1))*(Sl(i+1)-x(j));
           Mnl((i*2),j)=(-0.5/l(i+1))*(Sl(i+1)-x(j));
        end
        if j>Sl(i+1)+(i+1);
           Mnu((i*2)-1,j)=0;
           Mnl((i*2)-1,j)=0;
           Mnu((i*2),j)=0;
           Mnl((i*2),j)=0;
        end
    end
end
%calculate M3,M4,...M(n-2) (Horizontal beam)
for i=2:(nll-2);
    for j=1:sum(l)+nll;
        if j<=Sl(i-1)+(i-1);
           Mnu((i*2)-1,j)=0;
           Mnl((i*2)-1,j)=0;
           Mnu((i*2),j)=0;
           Mnl((i*2),j)=0;
        end
        if j>Sl(i-1)+(i-1);
           Mnu((i*2)-1,j)=((0.5/l(i))*(Sl(i)-x(j)))-1;
```

```
            Mnl((i*2)-1,j)=-(0.5/l(i))*(Sl(i)-x(j));
            Mnu((i*2),j)=-(0.5/l(i))*(Sl(i)-x(j));
            Mnl((i*2),j)=((0.5/l(i))*(Sl(i)-x(j)))-1;
        end
        if j>Sl(i)+i;
            Mnu((i*2)-1,j)=(-0.5/l(i+1))*(Sl(i+1)-x(j));
            Mnl((i*2)-1,j)=(0.5/l(i+1))*(Sl(i+1)-x(j));
            Mnu((i*2),j)=(0.5/l(i+1))*(Sl(i+1)-x(j));
            Mnl((i*2),j)=(-0.5/l(i+1))*(Sl(i+1)-x(j));
        end
        if j>Sl(i+1)+(i+1);
            Mnu((i*2)-1,j)=0;
            Mnl((i*2)-1,j)=0;
            Mnu((i*2),j)=0;
            Mnl((i*2),j)=0;
        end
    end
end
%calculate M(n-1),Mn (Horizontal beam)
for i=nll-1;
    for j=1:sum(l)+nll;
        if j<=Sl(i-1)+(i-1);
            Mnu((i*2)-1,j)=0;
            Mnl((i*2)-1,j)=0;
            Mnu((i*2),j)=0;
            Mnl((i*2),j)=0;
        end
        if j>Sl(i-1)+(i-1);
            Mnu((i*2)-1,j)=((0.5/l(i))*(Sl(i)-x(j)))-1;
            Mnl((i*2)-1,j)=-(0.5/l(i))*(Sl(i)-x(j));
            Mnu((i*2),j)=-(0.5/l(i))*(Sl(i)-x(j));
            Mnl((i*2),j)=((0.5/l(i))*(Sl(i)-x(j)))-1;
        end
    end
end
%=============================================================================
%Mn in cross beam.
%=============================================================================
% Mnc = bending moment(Mn) in cross beam.
%calculate M1,M2 (Cross beam)
for i=1;
    for q=1:nll;
        if q==i;
            for j=1:bb+1;
                Mnc((i*2)-1,q,j)=(-0.5/(bb/2))*((bb/2)-y(j));
                Mnc((i*2),q,j)=(-0.5/(bb/2))*((bb/2)-y(j));
            end
        end
        if q==i+1;
            for j=1:bb+1;
                Mnc((i*2)-1,q,j)=-(-0.5/(bb/2))*((bb/2)-y(j));
                Mnc((i*2),q,j)=-(-0.5/(bb/2))*((bb/2)-y(j));
            end
        end
        if q>=i+2;
            for j=1:bb+1;
                Mnc((i*2)-1,q,j)=0;
                Mnc((i*2),q,j)=0;
            end
        end
    end
end
%calculate M3,M4,...M(n-2) (Cross beam)
for i=2:(nll-2);
    for q=1:nll;
        if q<=i-1;
            for j=1:bb+1;
                Mnc((2*i)-1,q,j)=0;
                Mnc((2*i),q,j)=0;
            end
        end
        if q==i;
            for j=1:bb+1;
                Mnc((2*i)-1,q,j)=(-0.5/(bb/2))*((bb/2)-y(j));
                Mnc((2*i),q,j)=(-0.5/(bb/2))*((bb/2)-y(j));
            end
        end
```

```
        if q==i+1;
           for j=1:bb+1;
               Mnc((2*i)-1,q,j)=-(-0.5/(bb/2))*((bb/2)-y(j));
               Mnc((2*i),q,j)=-(-0.5/(bb/2))*((bb/2)-y(j));
           end
        end
        if q>=i+2;
           for j=1:bb+1;
               Mnc((2*i)-1,q,j)=0;
               Mnc((2*i),q,j)=0;
           end
        end
    end
end
%calculate M(n-1),Mn (Cross beam)
for i=n11-1;
    for q=1:n11;
        if q<=i-1;
           for j=1:bb+1;
               Mnc((2*i)-1,q,j)=0;
               Mnc((2*i),q,j)=0;
           end
        end
        if q==i;
           for j=1:bb+1;
               Mnc((2*i)-1,q,j)=(-0.5/(bb/2))*((bb/2)-y(j));
               Mnc((2*i),q,j)=(-0.5/(bb/2))*((bb/2)-y(j));
           end
        end
        if q>=n11;
           for j=1:bb+1;
               Mnc((2*i)-1,q,j)=((1/bb)*(bb-y(j)))-1;
               Mnc((2*i),q,j)=(1/bb)*(bb-y(j));
           end
        end
    end
end
%=========================================================================
%calculate bending moment(Mo) for integrate.
%=========================================================================
% pl = position of load.
for j=1:sum(l)+n11;
    for i=1:n+4;
        if x(j)==B(i);
           pl(i)=j;
        end
    end
end
% pc,pcl = position of cross beam.
for i=1:n11-1;
    pc(i)=Sl(i)+i;
    pcl(i)=Sl(i)+i+1;
end
% sl = position for find bending moment.
sl=[1 pl pc pcl];
sl=sort(sl);
%=========================================================================
% mioh = bending moment(Mo in horizontal beam) for integrate.
for j=1:sum(l)+n11;
    for i=1:1+(n+4)+(2*(n11-1))
        if j==sl(i);
           mioh(i)=Mox(j);
        end
    end
end
%=========================================================================
% mioc = bending moment(Mo in cross beam) for integrate.
for i=1:n11;
    mioc(i,1)=Moy(i,1);
    mioc(i,2)=Moy(i,(bb/2)+1);
    mioc(i,3)=Moy(i,bb+1);
end
%=========================================================================
%mix bending moment(Mn) before integrate.
%=========================================================================
% Mnmixu = mix bending moment(Mn) in upper beam.
% Mnmixl = mix bending moment(Mn) in lower beam.
```

```
% Mnmixc = mix bending moment(Mn) in cross beam.
for q=1:(n11-1);
    Mnmixu(q,:)=Mnu((q*2)-1,:)+Mnu(q*2,:);
    Mnmixl(q,:)=Mnl((q*2)-1,:)+Mnl(q*2,:);
    for k=1:n11;
        Mnmixc(q,k,:)=Mnc((q*2)-1,k,:)+Mnc(q*2,k,:);
    end
end
%=========================================================================
%calculate bending moment(Mn) for integrate.
%=========================================================================
% minu = bending moment(Mn in horizontal beam) in upper beam for integrate.
% minl = bending moment(Mn in horizontal beam) in lower beam for integrate.
for q=1:(n11-1);
for j=1:sum(l)+n11;
    for i=1:1+(n+4)+(2*(n11-1))
        if j==sl(i);
            minu(q,i)=Mnmixu(q,j);
            minl(q,i)=Mnmixl(q,j);
        end
    end
end
end
% minc = bending moment(Mn in cross beam) for integrate.
for q=1:(n11-1);
    for k=1:n11;
        minc(q,k,1)=Mnmixc(q,k,1);
        minc(q,k,2)=Mnmixc(q,k,(bb/2)+1);
        minc(q,k,3)=Mnmixc(q,k,bb+1);
    end
end
%=========================================================================
%Calculate integrate Mi*Mk.
%Integrate (Mi*Mk)=lh/6[Mia(2Mka+Mkb)+Mib(Mka+2Mkb)]
%=========================================================================
% Bl = position of length for find integrate bending moment.
Bl=[0 B Sl Sl];
Bl=sort(Bl);
% lh = length for integrate bending moment.
for i=1:(n+4)+(2*(n11-1));
    lh(i)=Bl(i+1)-Bl(i);
end
%=========================================================================
%Integrate Mn*Mn.
%=========================================================================
% immu = integrate bending moment(Mi*Mk) of upper beam.
% imml = integrate bending moment(Mi*Mk) of lower beam.
% Horizontal beam.
for i=1:(n11-1);
    for k=1:(n11-1);
        for j=1:(n+4)+(2*(n11-1));

imu(j)=(lh(j)/6)*((minu(i,j)*((2*minu(k,j))+minu(k,j+1))+(minu(i,j+1)*(minu(k,j)+(2*mi
nu(k,j+1))))));

iml(j)=(lh(j)/6)*((minl(i,j)*((2*minl(k,j))+minl(k,j+1))+(minl(i,j+1)*(minl(k,j)+(2*mi
nl(k,j+1))))));
        end
        immu(i,k)=sum(imu);
        imml(i,k)=sum(iml);
% Cross beam.
% immc = integrate bending moment(Mi*Mk) of cross beam.
        for q=1:n11;
            for j=1:2;

imc(j)=((bb/2)/6)*((minc(i,q,j)*((2*minc(k,q,j))+minc(k,q,j+1))+(minc(i,q,j+1)*(minc(k
,q,j)+(2*minc(k,q,j+1))))));
            end
            miximc(q)=(sum(imc))/Ic(q);
        end
        immc(i,k)=sum(miximc);
    end
end
%=========================================================================
%Integrate Mo*Mn.
%=========================================================================
% Horizontal beam.
```

```
% imomu = integrate bending moment(Mo*Mn) of upper beam.
% imoml = integrate bending moment(Mo*Mn) of lower beam.
for k=1:(nll-1);
    for j=1:(n+4)+(2*(nll-1));

imohu(j)=(lh(j)/6)*((mioh(j)*((2*minu(k,j))+minu(k,j+1))+(mioh(j+1)*(minu(k,j)+(2*minu
(k,j+1))))));

imohl(j)=(lh(j)/6)*((mioh(j)*((2*minl(k,j))+minl(k,j+1))+(mioh(j+1)*(minl(k,j)+(2*minl
(k,j+1))))));
    end
    imomu(k)=sum(imohu);
    imoml(k)=sum(imohl);
% Cross beam.
% imomc = integrate bending moment(Mo*Mn) of cross beam.
    for q=1:nll;
        for j=1:2;

imoc(j)=((bb/2)/6)*((mioc(q,j)*((2*minc(k,q,j))+minc(k,q,j+1))+(mioc(q,j+1)*(minc(k,q,
j)+(2*minc(k,q,j+1))))));
        end
        miximoc(q)=(sum(imoc))/Ic(q);
    end
    imomc(k)=sum(miximoc);
end
%=========================================================================
%calculate X from equation of [MM][X]=[MoM].
%=========================================================================
% MM = matrix Mn*Mn.
% MoM = matrix Mo*Mn.
MM=immu+imml+immc;
MoM=imomu+imoml+imomc;
X=inv(MM)*(-MoM');
%=========================================================================
% X1=X2,X3=X4,...,Xn=Xn-1 because chassis is symmety.
%=========================================================================
for i=1:(nll-1);
    Xn((2*i)-1)=X(i);
    Xn(2*i)=X(i);
end
%=========================================================================
%calculate bending moment from M=Mo+X1M1+X2M2+...+XnMn
%=========================================================================
%calculate M in horizontal beam.
%=========================================================================
% Mhu,Mhl = bending moment of upper and lower beam.
for i=1:2*(nll-1);
    Xnmu(i,:)=Xn(i)*Mnu(i,:);
    Xnml(i,:)=Xn(i)*Mnl(i,:);
end
Mhu=Mox+sum(Xnmu);          %(N.m)
Mhl=Mox+sum(Xnml);          %(N.m)
% Bending moment in upper beam and lower beam are the same.(Mhu=Mhl)
% Mh = bending moment in horizontal beam.
Mh=Mhu;
Mh=Mh/1000;                 % transform unit to kN.m
%=========================================================================
%calculate M in cross beam.
%=========================================================================
for i=1:2*(nll-1);
    for j=1:nll;
        Xnmc(i,j,:)=Xn(i)*Mnc(i,j,:);
    end
end
XMnc(:,:)=sum(Xnmc);
% Mc = bending moment in cross beam.
Mc=Moy+XMnc;                %(N.m)
Mc=Mc/1000;                 % transform unit to kN.m
%=========================================================================
%Plot length with bending moment in horizontal beam.
%=========================================================================
% x1,x2 = lower and upper beam.
% S2 = position of cross beam.
for j=1:sum(l)+nll;
    x1(j)=0;
    x2(j)=bb;
end
```

```
S2=[0 S1];
plotyy(x,x2,x,Mh)
title('Bending moment on horizontal beam.(kN.m)')
xlabel('Length < mm.>')
ylabel('Length < mm.>')
hold on
plot(x,x1)
for i=1:n11;
     for j=1:bb+1;
        y1(j)=S2(i);
     end
plot(y1,y)
grid on
axis('on')
end
hold off
%=========================================================================
%Plot length with bending moment in cross beam.
%=========================================================================
% Mc1 = bending moment in each cross beam.
figure
hold on
plot(x,x1)
plot(x,x2)
for i=1:n11;
     for j=1:bb+1;
        y1(j)=S2(i);
     end
    Mc1=(Mc(i,:)*500)+S2(i);
plot(y1,y)
plot(Mc1,y)
end
title('Bending moment on cross beam.(kN.m)')
xlabel('Length < mm.>')
ylabel('Length < mm.>')
grid on
axis('on')
hold off
%=========================================================================
```

4. โปรแกรมที่ใช้หาโมเมนต์ดัดจากภาระกรณีที่ 4

โปรแกรมนี้ใช้ในการคำนวณโมเมนต์ดัดที่เกิดจากการบิดตัวของโครงกรอบ

```
%=========================================================================
%case 4 (Torsion of chassis)
%Front wheel is lifted from the floor.(h=30 cm.)
%This program computes bending moment in the chassis.
%=========================================================================
clc
clear all
close all
%Input Data ==============================================================
%Change input data if another model.
%=========================================================================
l=[380 1502 802 910 1332 622];  %(Calculate only real integer in (mm.)
n11=7;       %Number of cross chassis beam.
bb=700;      %Chassis wide.(mm.)
sh=4.7;      %Horizontal beam thickness.(mm.)
bh=60;       %Horizontal beam wide.(mm.)
hh=190;      %Horizontal beam high.(mm.)
sc=[4.7 4.5 4.5 4.5 4 4.5 3];    %Cross beam thickness.(mm.)
bc=[60 60 110 75 75 110 35];           %Cross beam wide.(mm.)
hc=[120 110 175 175 165 140 130];    %Cross beam high.(mm.)
ksf=69.55;  %Spring constant of front wheel.(N/mm)
ksr=219.2;  %Spring constant of rear wheel.(N/mm)
ktf=490.5;  %Tire constant of front wheel.(N/mm)
ktr=981;    %Tire constant of rear wheel.(N/mm)
Sf=1400;    %Front wheel base.(mm.)
Sr=1450;    %Rear wheel base.(mm.)
```

```
Scf=700;     %(mm.)
Scr=700;     %(mm.)
L1=900;      %(mm.)
L2=3365;     %(mm.)
L3=1600;     %(mm.)
Lf1=575;     %(mm.)
Lf2=580;     %(mm.)
Lr1=614;     %(mm.)
Lr2=565;     %(mm.)
G=80850;     %Shear modolus (N/mm2)
E=210000;    %Young's modolus (N/mm2)
%=========================================================================
%Prepare data for calculation.
%force direction right and up is positive.
%force direction left and down is negative.
%=========================================================================
%Data in horizontal beam.
%=========================================================================
% Ith = Polar moment of inertia.(for standard case.)in horizontal beam.
Ith=(1/3)*((2*(bh*sh*sh*sh))+((hh-(2*sh))*sh*sh*sh));      %(mm4)
Xth=(bh-(sh/2))/(2+((hh-sh)/(3*(bh-(sh/2)))));             %(mm)
Iwh=(sh/3)*((hh-sh)/2)*((hh-sh)/2)*(bh-(sh/2))*(bh-(sh/2))*((2*(bh-(sh/2)))-(3*Xth));
%(mm6)
alfah=sqrt((G/E)*(Ith/Iwh));
allh=(alfah*l)/2;
% Itstarh = Polar moment of inertia.(for this case.)in horizontal beam.
Itstarh=Ith*(allh./(allh-tanh(allh)));                     %(mm4)
%=========================================================================
%Data in cross beam.
%=========================================================================
% Itc = Polar moment of inertia.(for standard case.)in cross beam.
for i=1:n11;
    Itc(i)=(1/3)*((2*(bc(i)*sc(i)*sc(i)*sc(i)))+((hc(i)-
(2*sc(i)))*sc(i)*sc(i)*sc(i)));  %(mm4)
    Xtc(i)=(bc(i)-(sc(i)/2))/(2+((hc(i)-sc(i))/(3*(bc(i)-(sc(i)/2)))));      %(mm)
    Iwc(i)=(sc(i)/3)*((hc(i)-sc(i))/2)*((hc(i)-sc(i))/2)*(bc(i)-(sc(i)/2))*(bc(i)-
(sc(i)/2))*((2*(bc(i)-(sc(i)/2)))-(3*Xtc(i))); %(mm6)
end
alfac=sqrt((G/E)*(Itc./Iwc));
% Xbar = line center of horizontal beam.
% lb = length of cross beam.
Xbar=((hh*sh*sh)+(2*2*sh*sh*(bh-sh))+(2*sh*(bh-sh)*(bh-sh)))/(2*((2*bh*sh)+((hh-
(2*sh))*sh)));
lb=bb-(2*Xbar);
allc=(alfac*lb)/2;
% Itstarc = Polar moment of inertia.(for this case.)in cross beam.
Itstarc=Itc.*(allc./(allc-tanh(allc)));                    %(mm4)
%=========================================================================
%Find Md from define Mr=P1*bt=1 N.mm
%=========================================================================
% bt = chassis wide.(effect of force cause bending only.)
bt=bb+(2*(Xth-(sh/2)));
% P1 = force from Mr=1 N.mm
P1=1/bt;          %(N.)
% Mdc = torsion of cross beam from Mr=1 N.mm
Mdc(1)=(P1*L2*Itstarc(1))/(sum(Itstarc)+((2/bt)*sum(Itstarh.*l)));
%=========================================================================
%Find next Mdc in cross beam.(Mr=1 N.mm)
%=========================================================================
for i=2:n11;
    Mdc(i)=Mdc(i-1)*(Itstarc(i)/Itstarc(i-1));             %(N.mm)
end
%=========================================================================
%Find Mdh in horizontal beam.(Mr=1 N.mm)
%=========================================================================
% Mdh = torsion of horizontal beam from Mr=1 N.mm
i=1;
Mdh(i)=Mdc(end)*(Itstarh(i)/Itstarc(end));
for i=2:n11-1;
    Mdh(i)=Mdh(i-1)*(Itstarh(i)/Itstarh(i-1));             %(N.mm)
end
%=========================================================================
%Find Ctr from Mr=1 N.mm
%=========================================================================
% Ctr = Overall chassis stiffness.
Ctr=G/(sum(l.*(Mdh.*Mdh)./Itstarh))+(sum(bb.*(Mdc.*Mdc)./Itstarc));   %(N.mm)
%=========================================================================
```

```
%Find bending moment (Mr) from h=30 cm.
%=========================================================================
% Mr = bending moment from h=30 cm.
Mr=(300/Sf)/((2/(Sf*Sf*ktf))+(2/(Scf*Scf*ksf))+(2/(Scr*Scr*ksr))+(2/(Sr*Sr*ktr))+(1/Ct
r));  %(N.mm)
%=========================================================================
%Find force on leaf spring from Mr=1 N.mm
%=========================================================================
% Rf1,Rf2 = reaction force on front leaf spring.
% Rr1,Rr2 = reaction force on rear leaf spring.
Rf1=(Lf2*-Pl)/(Lf1+Lf2);
Rf2=(-Pl-Rf1);
Rr1=(Lr2*Pl)/(Lr1+Lr2);
Rr2=Pl-Rr1;
%=========================================================================
%Find force in horizontal beam from Mr=1 N.mm
%=========================================================================
% Q,Q1 = force due to bending moment on cross beam.
Q(1)=(2/bt)*Mdh(1);
for i=2:n11-1;
    Q(i)=(2/bt)*(Mdh(i)-Mdh(i-1));
end
Q(n11)=-(2/bt)*Mdh(n11-1);
Q1=Q;
%=========================================================================
%Sort length and load for find bending moment.
%length for calculate.
%=========================================================================
% a,b = length of front and rear support of front leaf spring.
% c,d = length of front and rear support of rear leaf spring.
a=L1-Lf1;
b=L1+Lf2;
c=L1+L2-Lr1;
d=L1+L2+Lr2;
% S1 = length of cross beam.
S1=[0 cumsum(1)];
%=========================================================================
%If length of reaction force equal lenght of load.
%=========================================================================
i=1;
for j=1:100;
    if S1(i)==a;
         Rf1=Q(i)+Rf1;
       S1(i)=[];
        Q(i)=[];
         n11=n11-1;
    end
    if S1(i)==b;
         Rf2=Q(i)+Rf2;
       S1(i)=[];
        Q(i)=[];
         n11=n11-1;
    end
    if S1(i)==c;
         Rr1=Q(i)+Rr1;
       S1(i)=[];
        Q(i)=[];
         n11=n11-1;
    end
    if S1(i)==d;
         Rr2=Q(i)+Rr2;
       S1(i)=[];
        Q(i)=[];
         n11=n11-1;
    end
    if i>=n11;,break,end
    i=i+1;
end
% Sort length for find bending moment.
% A,B = length for find bending moment.
A=[S1 a b c d];
B=sort(A);
% w = load for calculate to find bending moment.
for i=1:n11+4;
       for k=1:n11;
           if B(i)==S1(k);
              w(i)=Q(k);
```

```
            end
        end
    if B(i)==a;
        w(i)=Rf1;
    end
    if B(i)==b;
        w(i)=Rf2;
    end
    if B(i)==c;
        w(i)=Rr1;
    end
    if B(i)==d;
        w(i)=Rr2;
    end
end
%=========================================================================
%Find bending moment in horizontal beam from Mr=1 N.mm
%=========================================================================
% m = bending moment in horizontal beam from Mr=1 N.mm
% find m from equation m(n)=m(n-1)-[(x-L(n))*w(n)]
k=0;
for j=1:100000;
    x(j)=k;
    m(j)=w(1)*x(j);
    for p=2:(n11+4);
        if x(j)>B(p);
            m(j)=m(j)+(w(p)*(x(j)-B(p)));       %(N.mm)
        end
    end
    if x(j)>=B(n11+4);,break,end
    k=k+1;
end
%=========================================================================
%Sort length and bending moment for plot length with bending moment.
%=========================================================================
%Sort length.
%=========================================================================
% x = new length after sort.
x=[x cumsum(l)];
x=sort(x);
%=========================================================================
%Sort bending moment.
%=========================================================================
%Add 0 in m for sort bending moment.
% m1 = new bending moment after sort.
m=[m 0];
k=1;
for i=1:sum(l)+n11;
    m1(i)=m(k);
    for q=2:n11;
        if i==S1(q)+q;
            k=k-1;
            m1(i)=m(k);
        end
    end
    k=k+1;
end
%=========================================================================
%Find bending moment in horizontal beam with effect from Mdc.
%=========================================================================
% m2 = bending moment in horizontal beam with effect from Mdc.
for i=1:sum(l)+n11;
    m2(i)=m1(i)+Mdc(1);
    for j=2:n11;
        if i>S1(j)+(j-1);
            m2(i)=m2(i)+Mdc(j);              %(N.mm)
        end
    end
end
%=========================================================================
%Find bending moment,force,torsion from Mr at h=30 cm.
%=========================================================================
% m3 = bending moment on horizontal beam from Mr at h=30 cm.
m3=Mr*m2;         %(N.mm)
% Rf11,Rf22 = reaction force on front leaf spring from Mr at h=30 cm.
% Rr11,Rr22 = reaction force on rear leaf spring from Mr at h=30 cm.
Rf11=Mr*Rf1;      %(N.)
```

```
Rf22=Mr*Rf2;      %(N.)
Rr11=Mr*Rr1;      %(N.)
Rr22=Mr*Rr2;      %(N.)
% Mdh1,Mdc1 = torsion of horizontal and cross beam from Mr at h=30 cm.
Mdh1=Mr*Mdh;      %(N.mm)
Mdc1=Mr*Mdc;      %(N.mm)
%=========================================================================
%Find bending moment in cross beam from Mr=1 N.mm
%=========================================================================
% my = bending moment in cross beam from Mr=1 N.mm
for i=1:nll;
    k=0;
    for j=1:1000000;
        y(j)=k;
        my(i,j)=Ql(i)*((bt/2)-k);     %(N.mm)
        if y(j)>=bt;,break,end
        k=k+1;
    end
end
%=========================================================================
%Find bending moment in cross beam from Mr at h=30 cm.
%=========================================================================
% myl = bending moment in cross beam from Mr at h=30 cm.
for i=1:nll;
    k=0;
    for j=1:1000000;
        y(j)=k;
        myl(i,j)=Mr*my(i,j);          %(N.mm)
        if y(j)>=bt;,break,end
        k=k+1;
    end
end
%=========================================================================
%change unit of bending moment.
m3=m3/1000000;          %(kN.m)
myl=myl/1000000;        %(kN.m)
%=========================================================================
%Plot length with bending moment.
%=========================================================================
%plot bending moment in horizontal beam.
plot(x,m3)
title('Bending moment Diagram for Case IV (Torsion of chassis)')
xlabel('Length < mm.>')
ylabel('Bending moment < kN.m >')
legend('Bending moment in Horizontal beam')
grid
axis('on')
%plot bending moment in cross beam.
for i=1:nll;
figure
plot(myl(i,:),y)
title('Bending moment Diagram for Case IV (Torsion of chassis)')
xlabel('Bending moment < kN.m >')
ylabel('Length < mm.>')
legend('Bending moment in Cross beam')
grid
axis('on')
end
%=========================================================================
```

5. โปรแกรมที่ใช้หาโมเมนต์ดัดจากภาระกรณีที่ 5

โปรแกรมที่ใช้ในการคำนวณโมเมนต์ดัดจากภาระกรณีนี้แบ่งออกเป็น 2 โปรแกรมคือ

5.1 โปรแกรมที่ใช้หาโมเมนต์ดัดจากภาระกรณีที่ 5a (การกระแทกในแนวดิ่งที่เพลาหน้า)

```
%=========================================================================
%case 5a (Vertical impact at front wheel)
%Force = 50% Weight on wheel.
%This program computes bending moment in horizontal beam.
```

```
%=========================================================================
clc
clear all
close all
%Input Data ==============================================================
%Change input data if another model.
%=========================================================================
L=[130 1340 1615 2065 2515 2965 3445 3895 4265 4665 5145 5545 5865];  %(mm.)
w1=400;     %(kg.)
w2=200;     %(kg.)
q=0.9412;  % distributed load.(kg/mm.)
mc=600;     % cab weight(kg.)
mf=2000;    % weight on front axle.(kg.)
mr=4000;    % weight on rear axle.(kg.)
mlf=200;    % weight of front axle.(kg.)
mlr=300;    % weight of rear axle.(kg.)
L1=900;     %(mm.)
L2=3365;    %(mm.)
L3=1600;    %(mm.)
Lf1=575;    %(mm.)
Lf2=580;    %(mm.)
Lr1=614;    %(mm.)
Lr2=565;    %(mm.)
lh=961;     % length of center of gravity to line of impact.(mm.)
Iy=14181050000;  % Mass moment of inertia for the truck (kg.mm2)
%=========================================================================
%calculate for reaction force.
% force direction right and up is positive.
% force direction left and down is negative.
%=========================================================================
[nn1,ind]=max(L);
n=ind;
% Av = impact force on front wheel.
% impact force = 50% Weight on wheel.
Av=(0.5*mf*9.81);
% z = linear acceleration of the truck.
% caculate only mass upper chassis frame.
z=Av/(mf+mr-mlf-mlr);
% aw = polar acceleration of the truck.
aw=(L2-lh)*Av/Iy;
% S = length of center of gravity.
S(1)=L(1)+((L(2)-L(1))*w2/mc);
for i=2:(n-2);
    S(i)=L(i+1)+((L(i+2)-L(i+1))/2);
end
li=(L1+L2-lh)-S;
% lp = length between pick-up truck support.
for i=1:(n-3)
lp(i)=L(i+3)-L(i+2);
end
% mi,mii = mass for caculate impact force.
mi=lp*q;
mii=[mc mi];
% Fidyn = impact force.
Fidyn=(mii.*(z+(li.*aw)));
% fidyn = impact force at chassis frame.
% fidyn(1)and fidyn(2)depend on cab weight.
fidyn(1)=(w1*Fidyn(1))/(w1+w2);
fidyn(2)=(Fidyn(1)-fidyn(1));
fidyn(3)=((Fidyn(2))/2);
for i=4:(n-1);
 fidyn(i)=(((Fidyn(i-2))/2)+((Fidyn(i-1))/2));
end
fidyn(n)=((Fidyn(n-2))/2);
% fidyn direction to down(negative).
fidyn=-fidyn;
% deltaRf,deltaRr = reaction force on front and rear wheel.
% find deltaRr from summation moment at front wheel equal zero.
deltaRr=-(sum(fidyn.*(L-L1)))/L2
deltaRf=-(sum(fidyn)+deltaRr)
% Rf1,Rf2 = reaction force on front leaf spring.
% Rr1,Rr2 = reaction force on rear leaf spring.
b1=Lf1+Lf2;
c1=Lf2*deltaRf;
Rf1=c1/b1
Rf2=deltaRf-Rf1
b2=Lr1+Lr2;
```

```
c2=Lr2*deltaRr;
Rr1=c2/b2
Rr2=deltaRr-Rr1
%=========================================================================
%length and load for calculate.
%=========================================================================
% a,b = length of front and rear support of front leaf spring.
% c,d = length of front and rear support of rear leaf spring.
a=L1-Lf1;
b=L1+Lf2;
c=L1+L2-Lr1;
d=L1+L2+Lr2;
%=========================================================================
%If length of reaction force equal lenght of load.
%=========================================================================
i=1;
for j=1:100;
    if L(i)==a;
        Rf1=fidyn(i)+Rf1;
   fidyn(i)=[];
       L(i)=[];
          n=n-1;
    end
    if L(i)==b;
        Rf2=fidyn(i)+Rf2;
   fidyn(i)=[];
       L(i)=[];
          n=n-1;
    end
    if L(i)==c;
        Rr1=fidyn(i)+Rr1;
   fidyn(i)=[];
       L(i)=[];
          n=n-1;
    end
    if L(i)==d;
        Rr2=fidyn(i)+Rr2;
   fidyn(i)=[];
       L(i)=[];
          n=n-1;
    end
  if i>=n;,break,end
     i=i+1;
end
% A,B = length for find bending moment.
A=[L a b c d];,B=sort(A);
% w = load for calculate.
for i=1:n+4;
        for j=1:n;
            if B(i)==L(j);
               w(i)=fidyn(j);
            end
        end
    if B(i)==a;
        w(i)=Rf1;
    end
    if B(i)==b;
        w(i)=Rf2;
    end
    if B(i)==c;
        w(i)=Rr1;
    end
    if B(i)==d;
        w(i)=Rr2;
    end
end
E=B;
F=B(1);
% length start to calculate at the first load.
B=B-B(1);
%=========================================================================
%calculate bending moment.
%=========================================================================
% x = length of horizontal chassis beam.
% m = bending moment.
% find m from equation m(n)=m(n-1)-[(x-L(n))*w(n)]k=0;
k=0;
```

```
for     j=1:100000;
        x(j)=k;
        m(j)=w(1)*x(j);
         for p=2:(n+4);
            if x(j)>B(p);
                m(j)=m(j)+(w(p)*(x(j)-B(p)));
            end
         end
   if x(j)>=B(n+4);,break,end
   k=k+1;
end
% length previous first load.
k=0;
for j=1:10000;
    f(j)=k;
    h(j)=0;
    if f(j)>=(F-2),break,end
    k=k+1;
end
% combine length previous first load.
x=x+F;
x=[f x];
% find bending moment in one beam.
m=m/2;
m=[h m];          %(N.mm)
% change unit of bending moment.
m1=m/1000000;     %(kN.m)
%=========================================================================
%Plot length with bending moment.
%=========================================================================
plot(x,m1)
title('Bending moment Diagram for Case 5a ( Vertical impact at front wheel )')
xlabel('Length < mm.>')
ylabel('Bending moment < kN.m >')
legend('Bending moment on horizontal beam')
grid
axis('on')
%=========================================================================
```

5.2 โปรแกรมที่ใช้หาโมเมนต์ดัดจากภาระกรณีที่ 5b (การกระแทกในแนวดิ่งที่เพลาหลัง)

```
%=========================================================================
%case 5b (Vertical impact at rear wheel)
%Force = 50% Weight on wheel.
%This program computes bending moment in horizontal beam.
%=========================================================================
clc
clear all
close all
%Input Data ==============================================================
%Change input data if another model.
%=========================================================================
L=[130 1340 1615 2065 2515 2965 3445 3895 4265 4665 5145 5545 5865];  %(mm.)
w1=400;     %(kg.)
w2=200;     %(kg.)
q=4000/4250;  % distributed load.(kg/mm.)
mc=600;     % cab weight(kg.)
mf=2000;    % weight on front axle.(kg.)
mr=4000;    % weight on rear axle.(kg.)
m1f=200;    % weight of front axle.(kg.)
m1r=300;    % weight of rear axle.(kg.)
L1=900;     %(mm.)
L2=3365;    %(mm.)
L3=1600;    %(mm.)
Lf1=575;    %(mm.)
Lf2=580;    %(mm.)
Lr1=614;    %(mm.)
Lr2=565;    %(mm.)
lh=961;     % length of center of gravity to line of impact.(mm.)
Iy=14181050000;  % Mass moment of inertia for the truck (kg.mm2)
%=========================================================================
```

```
%calculate for reaction force.
% force direction right and up is positive.
% force direction left and down is negative.
%=========================================================================
[nn1,ind]=max(L);
n=ind;
% Ah = impact force on rear wheel.
% impact force = 50% Weight on wheel.
Ah=(0.5*mr*9.81);
% z = linear acceleration of the truck.
% caculate only mass upper chassis frame.
z=Ah/(mf+mr-m1f-m1r);
% aw = polar acceleration of the truck.
aw=lh*Ah/Iy;
% S = length of center of gravity.
S(1)=L(1)+((L(2)-L(1))*w2/mc);
for i=2:(n-2);
    S(i)=L(i+1)+((L(i+2)-L(i+1))/2);
end
li=S-(L1+L2-lh);
% lp = length between pick-up truck support.
for i=1:(n-3)
lp(i)=L(i+3)-L(i+2);
end
% mi,mii = mass for caculate impact force.
mi=lp*q;
mii=[mc mi];
% Fidyn = impact force.
Fidyn=(mii.*(z+(li.*aw)));
% fidyn = impact force at chassis frame.
% fidyn(1)and fidyn(2)depend on cab weight.
fidyn(1)=(w1*Fidyn(1))/(w1+w2);
fidyn(2)=(Fidyn(1)-fidyn(1));
fidyn(3)=((Fidyn(2))/2);
for i=4:(n-1);
 fidyn(i)=(((Fidyn(i-2))/2)+((Fidyn(i-1))/2));
end
fidyn(n)=((Fidyn(n-2))/2);
% fidyn direction to down(negative).
fidyn=-fidyn;
% deltaRf,deltaRr = reaction force on front and rear wheel.
% find deltaRr from summation moment at front wheel equal zero.
deltaRr=-(sum(fidyn.*(L-L1)))/L2
deltaRf=-(sum(fidyn)+deltaRr)
% Rf1,Rf2 = reaction force on front leaf spring.
% Rr1,Rr2 = reaction force on rear leaf spring.
b1=Lf1+Lf2;
c1=Lf2*deltaRf;
Rf1=c1/b1
Rf2=deltaRf-Rf1
b2=Lr1+Lr2;
c2=Lr2*deltaRr;
Rr1=c2/b2
Rr2=deltaRr-Rr1
%=========================================================================
%length and load for calculate.
%=========================================================================
% a,b = length of front and rear support of front leaf spring.
% c,d = length of front and rear support of rear leaf spring.
a=L1-Lf1;
b=L1+Lf2;
c=L1+L2-Lr1;
d=L1+L2+Lr2;
%=========================================================================
%If length of reaction force equal lenght of load.
%=========================================================================
i=1;
for j=1:100;
    if L(i)==a;
        Rf1=fidyn(i)+Rf1;
   fidyn(i)=[];
       L(i)=[];
          n=n-1;
    end
    if L(i)==b;
        Rf2=fidyn(i)+Rf2;
   fidyn(i)=[];
```

```
       L(i)=[];
          n=n-1;
    end
    if L(i)==c;
        Rr1=fidyn(i)+Rr1;
   fidyn(i)=[];
       L(i)=[];
          n=n-1;
    end
    if L(i)==d;
        Rr2=fidyn(i)+Rr2;
   fidyn(i)=[];
       L(i)=[];
          n=n-1;
    end
  if i>=n;,break,end
     i=i+1;
end
% A,B = length for find bending moment.
A=[L a b c d];,B=sort(A);
% w = load for calculate.
for i=1:n+4;
        for j=1:n;
            if B(i)==L(j);
               w(i)=fidyn(j);
            end
        end
    if B(i)==a;
        w(i)=Rf1;
    end
    if B(i)==b;
        w(i)=Rf2;
    end
    if B(i)==c;
        w(i)=Rr1;
    end
    if B(i)==d;
        w(i)=Rr2;
    end
end
E=B;
F=B(1);
% length start to calculate at the first load.
B=B-B(1);
%=============================================================================
%calculate bending moment.
%=============================================================================
% x = length of horizontal chassis beam.
% m = bending moment.
% find m from equation m(n)=m(n-1)-[(x-L(n))*w(n)]k=0;
k=0;
for    j=1:100000;
       x(j)=k;
       m(j)=w(1)*x(j);
        for p=2:(n+4);
           if x(j)>B(p);
               m(j)=m(j)+(w(p)*(x(j)-B(p)));
           end
        end
   if x(j)>=B(n+4);,break,end
   k=k+1;
end
% length previous first load.
k=0;
for j=1:10000;
    f(j)=k;
    h(j)=0;
    if f(j)>=(F-2),break,end
    k=k+1;
end
% combine length previous first load.
x=x+F;
x=[f x];
% find bending moment in one beam.
m=m/2;
m=[h m];          %(N.mm)
% change unit of bending moment.
```

```
ml=m/1000000;     %(kN.m)
%=========================================================================
%Plot length with bending moment.
%=========================================================================
plot(x,ml)
title('Bending moment Diagram for Case 5b ( Vertical impact at rear wheel )')
xlabel('Length < mm.>')
ylabel('Bending moment < kN.m >')
legend('Bending moment on horizontal beam')
grid
axis('on')
%=========================================================================
```

5. โปรแกรมที่ใช้หาโมเมนต์ดัดจากภาระกรณีที่ 7

โปรแกรมนี้ใช้ในการคำนวณหาโมเมนต์ดัดที่เกิดจากการรับแรงในแนวตามยาวของโครงกรอบที่ไม่เท่ากันทั้งสองข้าง เนื่องจากผลต่างของสัมประสิทธิ์แรงเสียดทานและระหว่างล้อรถกับถนน

```
%=========================================================================
%case 7 (Load on chassis plane by friction coefficient difference = 0.5)
%Effect of horizontal load.
%This program computes bending moment in the plane chassis.
%=========================================================================
clc
clear all
close all
%Input Data ==============================================================
%Change input data if another model.
%=========================================================================
l=[417 1502 802 910 1332 622];  %(mm.)
nll=7;      %number of cross chassis beam.
mf=1687.45*2;    %weight on front axle.(kg.)
mr=3402.55*2;    %weight on rear axle.(kg.)
bb=700;     %chassis wide.(mm.)
Sv=1400;    %Front wheel base.(mm.)
Sh=1450;    %Rear wheel base.(mm.)
L1=900;     %(mm.)
L2=3365;    %(mm.)
L3=1600;    %(mm.)
Lf1=575;    %(mm.)
Lf2=580;    %(mm.)
Lr1=614;    %(mm.)
Lr2=565;    %(mm.)
%=========================================================================
%calculate reaction force.
%calculate only real positive integers length in mm.
%=========================================================================
% force direction right and up is positive.
% force direction left and down is negative.
Pv=(mf/2)*9.81*0.5;
Ph=(mr/2)*9.81*0.5;
% Fhu,Fhl = force on upper and lower beam.
Fhu=((0.5*Pv*Sv)/(2*bb))+((0.5*Ph*Sh)/(2*bb))
Fhl=-Fhu
% Rf,Rr = reaction force on horizontal plane at front and rear wheel.
Rf=-0.5*((Pv*Sv)+(Ph*Sh))/(2*L2)
Rr=-Rf
% Rf1,Rf2 = reaction force on front leaf spring.
% Rr1,Rr2 = reaction force on rear leaf spring.
Rf1=(Lf2*Rf)/(Lf1+Lf2)
Rf2=Rf-Rf1
Rr1=(Lr2*Rr)/(Lr1+Lr2)
Rr2=Rr-Rr1
%=========================================================================
%length and load for calculate.
%=========================================================================
% a,b = length of front and rear support of front leaf spring.
```

```
% c,d = length of front and rear support of rear leaf spring.
a=L1-Lf1;
b=L1+Lf2;
c=L1+L2-Lr1;
d=L1+L2+Lr2;
% B = length of load for find bending moment.
B=[a b c d];
% w = load for calculate to find bending moment.
w=[Rf1/2 Rf2/2 Rr1/2 Rr2/2];
%=========================================================================
%Calculation internal force form external force.
%normal force in cross chsssis beam is 0.Because is easy to create program.
%=========================================================================
%av = internal force on vertical plane.
%=========================================================================
% S1 = cumulate l.
S1=cumsum(l);
for k=1:(n11-1);
    for i=1:4;
        if B(i)<S1(k);
           qv(i)=w(i);
        end
        if B(i)>=S1(k);
           qv(i)=0;
        end
    end
    av(k)=-sum(qv);
end
%=========================================================================
%ah = internal force on horizontal plane.
%=========================================================================
% aaa = summation moment of external force.
%first loop.
for k=1;
    aaa(k)=0;
    for i=1:4;
       if B(i)<S1(k);
          qh(i)=(w(i)*B(i));
          aaa(k)=sum(qh);
       end
    end
    ah(k)=-(aaa(k)+(l(k)*av(k)))/(bb/2);
end
%next loop.
for k=2:(n11-1);
    aaa(k)=0;
    for i=1:4;
       if B(i)>=S1(k-1);
          if B(i)<S1(k);
             qh(i)=(w(i)*(B(i)-S1(k-1)));
             aaa(k)=sum(qh);
          end
       end
    end
    if aaa(k)~=0;
       for j=1:k-1;
          aaa(k)=aaa(k)-aaa(k-j);
       end
    end
    ah(k)=-(aaa(k)+(l(k)*av(k)))/(bb/2);
end
%=========================================================================
%calculate Mo(bending moment) from external force.
%=========================================================================
%Find Mo from external force.
% mx1 = bending moment from external force.
for i=1:4;
    %case 1.
    if B(i)<=S1(1)
       k=0;
       for  j=1:1000000;
            x(j)=k;
            mx1(i,j)=-w(i)*(B(i)-k);
            if x(j)>=B(i)
               mx1(i,j)=0;
               if x(j)>=S1(n11-1);,break,end
            end
```

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```
            k=k+1;
        end
    end
    %case 2.
    if B(i)>Sl(l);
       for q=2:(nll-1);
         if B(i)>=Sl(q-1);
           k=0;
           kl=0;
           for j=1:1000000;
               x(j)=k;
               mxl(i,j)=0;
               if x(j)>=Sl(q-1);
                  mxl(i,j)=-w(i)*((B(i)-Sl(q-1))-kl);
                  kl=kl+1;
               end
               if x(j)>=B(i);
                  mxl(i,j)=0;
               end
               k=k+1;
               if x(j)>=Sl(nll-1);,break,end
           end
         end
       end
    end
end
%=========================================================================
% mxl0 = add one column in mxl for find mxlnew.
%=========================================================================
mxl0=[sum(mxl) 0];
% mxlnew = new bending moment from mxl.
k=1;
for j=1:sum(l)+nll;
    mxlnew(j)=mxl0(k);
    for q=1:nll-1;
        if j==Sl(q)+q;
           k=k-1;
           mxlnew(j)=mxl0(k);
        end
    end
    k=k+1;
end
mxlnew=mxlnew/1000;        % transform unit to N.m
%=========================================================================
%calculate Mo from av(vertical internal force).
%=========================================================================
% mx2 = bending moment from vertical internal force.
%first loop.
for i=1;
    k=0;
    for  j=1:1000000;
         x(j)=k;
         mx2(i,j)=-(av(i)*(Sl(i)-k));
         if x(j)>Sl(i);
            mx2(i,j)=0;
         end
         if x(j)>=Sl(nll-1);,break,end
         k=k+1;
    end
end
%next loop.
for i=2:nll-2;
    k=0;
    for  j=1:1000000;
         x(j)=k;
         mx2(i,j)=0;
         if x(j)>=Sl(i-1);
            mx2(i,j)=-(av(i)*(Sl(i)-k));
         end
         if x(j)>Sl(i);
            mx2(i,j)=0;
         end
         if x(j)>=Sl(nll-1);,break,end
         k=k+1;
    end
end
%end loop.
```

```
for i=nll-1;
    k=0;
    for  j=1:1000000;
         x(j)=k;
         mx2(i,j)=0;
         if x(j)>=Sl(i-1);
            mx2(i,j)=-(av(i)*(Sl(i)-k));
         end
         if x(j)>=Sl(nll-1);,break,end
         k=k+1;
    end
end
%=========================================================================
% mx20 = add one column in mx2 for find mx2new.
%=========================================================================
mx20=[sum(mx2) 0];
% mx2new = new bending moment from mx2.
k=1;
for j=1:sum(l)+nll;
    mx2new(j)=mx20(k);
    for q=1:nll-1;
        if j==Sl(q)+q;
           k=k-1;
           mx2new(j)=0;
        end
    end
    k=k+1;
end
mx2new=mx2new/1000;          % transform unit to N.m
%=========================================================================
% Mox = bending moment from external force in horizontal beam.
%=========================================================================
Mox=mx1new+mx2new;           %(N.m)
%=========================================================================
% x = length in x-axle for find bending moment.
% y = length in y-axle for find bending moment.
x=[x Sl];
x=sort(x);
y=[0:bb];
%=========================================================================
%Find Mo from ah(internal force).
%=========================================================================
% Moy = bending moment from external force in cross beam.
for  q=1:nll;
     for j=1:bb+1;
         if q<=(nll-1);
            Moy(q,j)=ah(q)*((bb/2)-y(j));
         end
         if q==nll;
            Moy(q,j)=0;
         end
     end
end
Moy=Moy/1000;                % transform unit to N.m
%=========================================================================
%calculate Mn from assume Xn=1 N.m
%Mn in horizontal beam.
%=========================================================================
% Mnu = bending moment(Mn) in upper beam.
% Mnl = bending moment(Mn) in lower beam.
%calculate M1,M2 (Horizontal beam)
for i=1;
    for j=1:sum(l)+nll;
        Mnu((i*2)-1,j)=((0.5/l(i))*(Sl(i)-x(j)))-1;
        Mnl((i*2)-1,j)=-(0.5/l(i))*(Sl(i)-x(j));
        Mnu((i*2),j)=-(0.5/l(i))*(Sl(i)-x(j));
        Mnl((i*2),j)=((0.5/l(i))*(Sl(i)-x(j)))-1;
        if j>Sl(i)+i;
           Mnu((i*2)-1,j)=(-0.5/l(i+1))*(Sl(i+1)-x(j));
           Mnl((i*2)-1,j)=(0.5/l(i+1))*(Sl(i+1)-x(j));
           Mnu((i*2),j)=(0.5/l(i+1))*(Sl(i+1)-x(j));
           Mnl((i*2),j)=(-0.5/l(i+1))*(Sl(i+1)-x(j));
        end
        if j>Sl(i+1)+(i+1);
           Mnu((i*2)-1,j)=0;
           Mnl((i*2)-1,j)=0;
           Mnu((i*2),j)=0;
```

```
            Mnl((i*2),j)=0;
        end
    end
end
%calculate M3,M4,...M(n-2) (Horizontal beam)
for i=2:(nl1-2);
    for j=1:sum(l)+nl1;
        if j<=Sl(i-1)+(i-1);
            Mnu((i*2)-1,j)=0;
            Mnl((i*2)-1,j)=0;
            Mnu((i*2),j)=0;
            Mnl((i*2),j)=0;
        end
        if j>Sl(i-1)+(i-1);
            Mnu((i*2)-1,j)=((0.5/l(i))*(Sl(i)-x(j)))-1;
            Mnl((i*2)-1,j)=-(0.5/l(i))*(Sl(i)-x(j));
            Mnu((i*2),j)=-(0.5/l(i))*(Sl(i)-x(j));
            Mnl((i*2),j)=((0.5/l(i))*(Sl(i)-x(j)))-1;
        end
        if j>Sl(i)+i;
            Mnu((i*2)-1,j)=(-0.5/l(i+1))*(Sl(i+1)-x(j));
            Mnl((i*2)-1,j)=(0.5/l(i+1))*(Sl(i+1)-x(j));
            Mnu((i*2),j)=(0.5/l(i+1))*(Sl(i+1)-x(j));
            Mnl((i*2),j)=(-0.5/l(i+1))*(Sl(i+1)-x(j));
        end
        if j>Sl(i+1)+(i+1);
            Mnu((i*2)-1,j)=0;
            Mnl((i*2)-1,j)=0;
            Mnu((i*2),j)=0;
            Mnl((i*2),j)=0;
        end
    end
end
%calculate M(n-1),Mn (Horizontal beam)
for i=nl1-1;
    for j=1:sum(l)+nl1;
        if j<=Sl(i-1)+(i-1);
            Mnu((i*2)-1,j)=0;
            Mnl((i*2)-1,j)=0;
            Mnu((i*2),j)=0;
            Mnl((i*2),j)=0;
        end
        if j>Sl(i-1)+(i-1);
            Mnu((i*2)-1,j)=((0.5/l(i))*(Sl(i)-x(j)))-1;
            Mnl((i*2)-1,j)=-(0.5/l(i))*(Sl(i)-x(j));
            Mnu((i*2),j)=-(0.5/l(i))*(Sl(i)-x(j));
            Mnl((i*2),j)=((0.5/l(i))*(Sl(i)-x(j)))-1;
        end
    end
end
%=========================================================================
%Mn in cross beam.
%=========================================================================
% Mnc = bending moment(Mn) in cross beam.
%calculate M1,M2 (Cross beam)
for i=1;
    for q=1:nl1;
        if q==i;
            for j=1:bb+1;
                Mnc((i*2)-1,q,j)=(-0.5/(bb/2))*((bb/2)-y(j));
                Mnc((i*2),q,j)=(-0.5/(bb/2))*((bb/2)-y(j));
            end
        end
        if q==i+1;
            for j=1:bb+1;
                Mnc((i*2)-1,q,j)=-(-0.5/(bb/2))*((bb/2)-y(j));
                Mnc((i*2),q,j)=-(-0.5/(bb/2))*((bb/2)-y(j));
            end
        end
        if q>=i+2;
            for j=1:bb+1;
                Mnc((i*2)-1,q,j)=0;
                Mnc((i*2),q,j)=0;
            end
        end
    end
end
```

```
%calculate M3,M4,...M(n-2) (Cross beam)
for i=2:(nll-2);
    for q=1:nll;
        if q<=i-1;
           for j=1:bb+1;
               Mnc((2*i)-1,q,j)=0;
               Mnc((2*i),q,j)=0;
           end
        end
        if q==i;
           for j=1:bb+1;
               Mnc((2*i)-1,q,j)=(-0.5/(bb/2))*((bb/2)-y(j));
               Mnc((2*i),q,j)=(-0.5/(bb/2))*((bb/2)-y(j));
           end
        end
        if q==i+1;
           for j=1:bb+1;
               Mnc((2*i)-1,q,j)=-(-0.5/(bb/2))*((bb/2)-y(j));
               Mnc((2*i),q,j)=-(-0.5/(bb/2))*((bb/2)-y(j));
           end
        end
        if q>=i+2;
           for j=1:bb+1;
               Mnc((2*i)-1,q,j)=0;
               Mnc((2*i),q,j)=0;
           end
        end
    end
end
%calculate M(n-1),Mn (Cross beam)
for i=nll-1;
    for q=1:nll;
        if q<=i-1;
           for j=1:bb+1;
               Mnc((2*i)-1,q,j)=0;
               Mnc((2*i),q,j)=0;
           end
        end
        if q==i;
           for j=1:bb+1;
               Mnc((2*i)-1,q,j)=(-0.5/(bb/2))*((bb/2)-y(j));
               Mnc((2*i),q,j)=(-0.5/(bb/2))*((bb/2)-y(j));
           end
        end
        if q>=nll;
           for j=1:bb+1;
               Mnc((2*i)-1,q,j)=((1/bb)*(bb-y(j)))-1;
               Mnc((2*i),q,j)=(1/bb)*(bb-y(j));
           end
        end
    end
end
%=========================================================================
%calculate bending moment(Mo) for integrate.
%=========================================================================
% pl = position of load.
for j=1:sum(l)+nll;
    for i=1:4;
        if x(j)==B(i);
           pl(i)=j;
        end
    end
end
% pc,pcl = position of cross beam.
for i=1:nll-1;
    pc(i)=Sl(i)+i;
    pcl(i)=Sl(i)+i+1;
end
% sl = position for find bending moment.
sl=[1 pl pc pcl];
si=sort(sl);
%=========================================================================
% mioh = bending moment(Mo in horizontal beam) for integrate.
for j=1:sum(l)+nll;
    for i=1:1+4+(2*(nll-1))
        if j==sl(i);
           mioh(i)=Mox(j);
```

```
        end
    end
end
%=========================================================================
% mioc = bending moment(Mo in cross beam) for integrate.
for i=1:nll;
    mioc(i,1)=Moy(i,1);
    mioc(i,2)=Moy(i,(bb/2)+1);
    mioc(i,3)=Moy(i,bb+1);
end
%=========================================================================
%mix bending moment(Mn) before integrate.
%=========================================================================
% Mnmixu = mix bending moment(Mn) in upper beam.
% Mnmixl = mix bending moment(Mn) in lower beam.
% Mnmixc = mix bending moment(Mn) in cross beam.
for q=1:(nll-1);
    Mnmixu(q,:)=Mnu((q*2)-1,:)+Mnu(q*2,:);
    Mnmixl(q,:)=Mnl((q*2)-1,:)+Mnl(q*2,:);
    for k=1:nll;
        Mnmixc(q,k,:)=Mnc((q*2)-1,k,:)+Mnc(q*2,k,:);
    end
end
%=========================================================================
%calculate bending moment(Mn) for integrate.
%=========================================================================
% minu = bending moment(Mn in horizontal beam) in upper beam for integrate.
% minl = bending moment(Mn in horizontal beam) in lower beam for integrate.
for q=1:(nll-1);
for j=1:sum(l)+nll;
    for i=1:1+4+(2*(nll-1))
        if j==sl(i);
            minu(q,i)=Mnmixu(q,j);
            minl(q,i)=Mnmixl(q,j);
        end
    end
end
end
% minc = bending moment(Mn in cross beam) for integrate.
for q=1:(nll-1);
    for k=1:nll;
        minc(q,k,1)=Mnmixc(q,k,1);
        minc(q,k,2)=Mnmixc(q,k,(bb/2)+1);
        minc(q,k,3)=Mnmixc(q,k,bb+1);
    end
end
%=========================================================================
%Calculate integrate Mi*Mk.
%Integrate (Mi*Mk)=lh/6[Mia(2Mka+Mkb)+Mib(Mka+2Mkb)]
%=========================================================================
% Bl = position of length for find integrate bending moment.
Bl=[0 B Sl Sl];
Bl=sort(Bl);
% lh = length for integrate bending moment.
for i=1:4+(2*(nll-1));
    lh(i)=Bl(i+1)-Bl(i);
end
%=========================================================================
%Integrate Mn*Mn.
%=========================================================================
% immu = integrate bending moment(Mi*Mk) of upper beam.
% imml = integrate bending moment(Mi*Mk) of lower beam.
% Horizontal beam.
for i=1:(nll-1);
    for k=1:(nll-1);
        for j=1:4+(2*(nll-1));

imu(j)=(lh(j)/6)*((minu(i,j)*((2*minu(k,j))+minu(k,j+1))+(minu(i,j+1)*(minu(k,j)+(2*mi
nu(k,j+1)))));

iml(j)=(lh(j)/6)*((minl(i,j)*((2*minl(k,j))+minl(k,j+1))+(minl(i,j+1)*(minl(k,j)+(2*mi
nl(k,j+1))))));
        end
        immu(i,k)=sum(imu);
        imml(i,k)=sum(iml);
% Cross beam.
% immc = integrate bending moment(Mi*Mk) of cross beam.
```

```
        for q=1:nll;
            for j=1:2;

imc(j)=((bb/2)/6)*((minc(i,q,j)*((2*minc(k,q,j))+minc(k,q,j+1))+(minc(i,q,j+1)*(minc(k
,q,j)+(2*minc(k,q,j+1))))));
            end
            miximc(q)=sum(imc);
        end
        immc(i,k)=sum(miximc);
    end
end
%=========================================================================
%Integrate Mo*Mn.
%=========================================================================
% Horizontal beam.
% imomu = integrate bending moment(Mo*Mn) of upper beam.
% imoml = integrate bending moment(Mo*Mn) of lower beam.
for k=1:(nll-1);
    for j=1:4+(2*(nll-1));

imohu(j)=(lh(j)/6)*((mioh(j)*((2*minu(k,j))+minu(k,j+1))+(mioh(j+1)*(minu(k,j)+(2*minu
(k,j+1))))));

imohl(j)=(lh(j)/6)*((mioh(j)*((2*minl(k,j))+minl(k,j+1))+(mioh(j+1)*(minl(k,j)+(2*minl
(k,j+1))))));
    end
    imomu(k)=sum(imohu);
    imoml(k)=sum(imohl);
% Cross beam.
% imomc = integrate bending moment(Mo*Mn) of cross beam.
    for q=1:nll;
        for j=1:2;

imoc(j)=((bb/2)/6)*((mioc(q,j)*((2*minc(k,q,j))+minc(k,q,j+1))+(mioc(q,j+1)*(minc(k,q,
j)+(2*minc(k,q,j+1))))));
        end
        miximoc(q)=sum(imoc);
    end
    imomc(k)=sum(miximoc);
end
%=========================================================================
%calculate X from equation of [MM][X]=[MoM].
%=========================================================================
% MM = matrix Mn*Mn.
% MoM = matrix Mo*Mn.
MM=immu+imml+immc;
MoM=imomu+imoml+imomc;
X=inv(MM)*(-MoM');
%=========================================================================
% X1=X2,X3=X4,...,Xn=Xn-1 because chassis is symmety.
%=========================================================================
for i=1:(nll-1);
    Xn((2*i)-1)=X(i);
    Xn(2*i)=X(i);
end
%=========================================================================
%calculate bending moment from M=Mo+X1M1+X2M2+...+XnMn
%=========================================================================
%calculate M in horizontal beam.
%=========================================================================
% Mhu,Mhl = bending moment of upper and lower beam.
for i=1:2*(nll-1);
    Xnmu(i,:)=Xn(i)*Mnu(i,:);
    Xnml(i,:)=Xn(i)*Mnl(i,:);
end
Mhu=Mox+sum(Xnmu);          %(N.m)
Mhl=Mox+sum(Xnml);          %(N.m)
% Bending moment in upper beam and lower beam are the same.(Mhu=Mhl)
% Mh = bending moment in horizontal beam.
Mh=Mhu;
Mh=Mh/1000;                 % transform unit to kN.m
%=========================================================================
%calculate M in cross beam.
%=========================================================================
for i=1:2*(nll-1);
    for j=1:nll;
        Xnmc(i,j,:)=Xn(i)*Mnc(i,j,:);
```

```
    end
end
XMnc(:,:)=sum(Xnmc);
% Mc = bending moment in cross beam.
Mc=Moy+XMnc;                %(N.m)
Mc=Mc/1000;                 % transform unit to kN.m
%=========================================================================
%Plot length with bending moment.
%=========================================================================
%Horizontal beam.
plot(x,Mh)
title('Bending moment Diagram for Case 7 ( Friction coefficient difference = 0.5 )')
xlabel('Length < mm.>')
ylabel('Bending moment < kN.m >')
legend('Bending moment on horizontal beam')
grid
axis('on')
%Cross beam.
for i=1:n11;
figure
plot(Mc(i,:),y)
title('Bending moment Diagram for Case 7 ( Friction coefficient difference = 0.5 )')
xlabel('Bending moment < kN.m >')
ylabel('Length < mm.>')
legend('Bending moment on cross beam')
grid
axis('on')
end
%=========================================================================
```

ประวัติผู้เขียนวิทยานิพนธ์

นาย อมรศักดิ์ ฉ่ำแก้ว เกิดเมื่อวันที่ 25 พฤษภาคม 2523 ที่จังหวัดอุทัยธานี สำเร็จการศึกษาปริญญาวิศวกรรมศาสตรบัณฑิต สาขาวิศวกรรมเครื่องกล จากภาควิชาวิศวกรรมเครื่องกล คณะวิศวกรรมศาสตร์ มหาวิทยาลัยเกษตรศาสตร์ เมื่อปีการศึกษา 2544 และเข้าศึกษาต่อในหลักสูตรวิศวกรรมศาสตรมหาบัณฑิต ภาควิชาวิศวกรรมเครื่องกล คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย เมื่อปีการศึกษา 2545