7 The Singapore Mass Rapid Transit (SMRT) started its first train services in 1987. It was a massive nationwide project, beginning from the physical construction of the train tracks to the planning of the train arrival frequency. Amongst other professionals, the project involved the close collaboration of civil and structural engineers as well as transport engineers.

The Kawasaki Heavy Industries (KHI) C151 train as shown in Fig. 7.1, is Singapore's first generation of SMRT train fleet and has been in passenger service since 7 November 1987. All of the 396 KHI cars are built from 1986 to 1989 by four manufacturers in the consortium led by Kawasaki Heavy Industries.

Fig. 7.1

<u>Technical Specifications:</u>

Manufacturer:	Kawasaki Heavy Industries, Nippon Sharyo, Tokyu Car Corporation, Kinki Sharyo
Number built:	396 cars (66 trains)
Car body Construction:	Aluminium-alloy construction
Maximum Speed:	90 km h^{-1} (Design)
	80 km h^{-1} (Service)
Train Length:	138 m (for the 6 cars in one train)
Width:	3.2 m
Height:	3.7 m
Train Mass:	286000 kg (fully laden)
Doors:	1.45 m, 8 per car
Seating Capacity:	208 seats

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Fig. 7.2 shows a section of an elevated MRT track with a train on it. From the structural aspect, the structure load is being supported as follows:

1. Each car, with passengers in it, has its load supported by the beam below it. Car 2 is thus supported by beam 2.
2. Car 2 and beam 2 are both supported by columns 1 and 2.

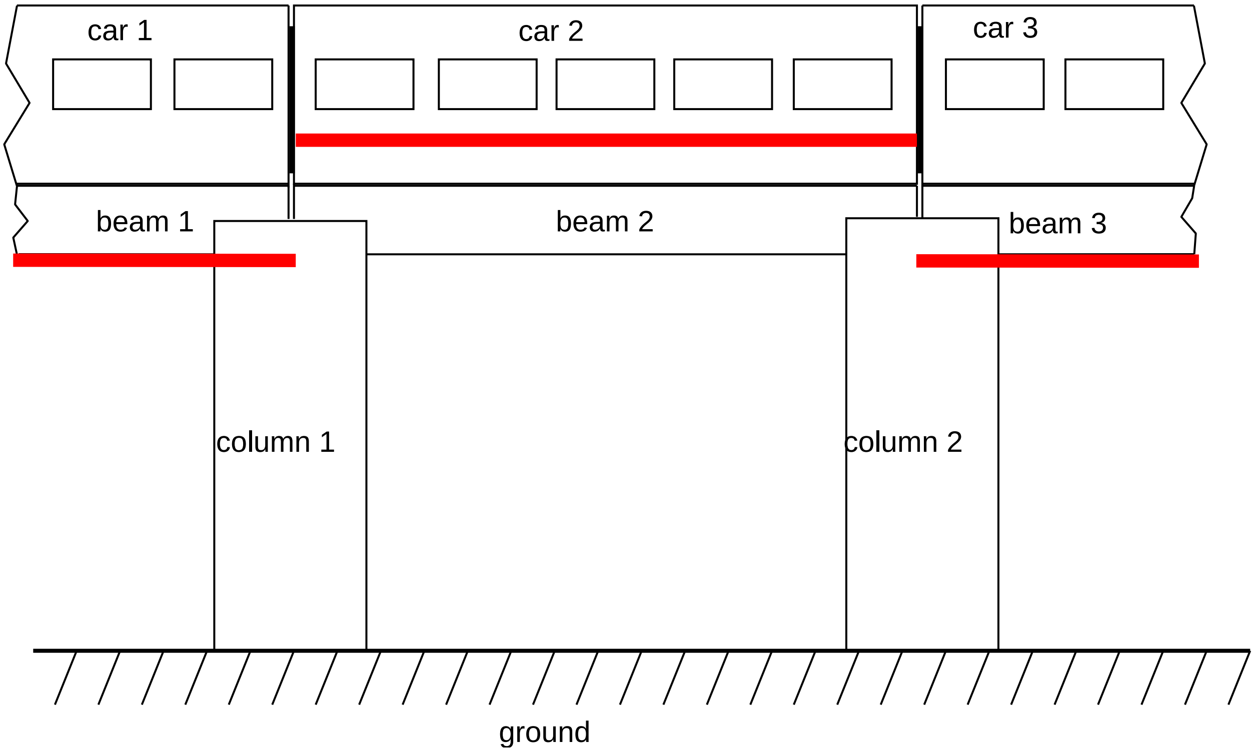

Fig. 7.2

The following set of simplified data is provided.

Weight of 1 empty car = 350 kN

Weight of 1 beam = 380 kN

Weight of 1 column = 100 kN

(a) Explain what is meant by *train arrival frequency*.

…………………………………………………………………………..………………………............... [1]

(b) An alloy is a combination of metals or of a metal and another element.

Suggest why trains are commonly made of aluminium alloy.

…………………………………………………………………………..……………………………........ [1]

(c) When a train with no passengers in it, and is at the position shown in Fig. 7.2,

(i) State whether the bottom of beam 2 is under compression or tension.

…………………………………………………………………………..……………………….......... [1]

(ii) calculate the total normal reaction force acting on beam 2 due to the supporting columns.

normal force = ……………….......……..... N [1]

(iii) Hence, state the total load that the top of column 1 has to take.

total load = ……………….......……..... N [1]

(iv) calculate the total load that the ground directly below each column has to take.

total load = ……………….......……..... N [2]

(d) An engineer needs to design the structure such that the ground does not cave in when a fully loaded train passes overhead. In designing the structure loading, a factor of safety is incorporated.

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$$\text{Factor of safety} = \frac{\text{maximum stress}}{\text{applied stress}} = \frac{\text{maximum load}}{\text{applied load}}$$

Maximum stress is defined as the maximum force the ground can withstand per unit cross-sectional area.

Applied stress is defined as the applied force the ground withstands F, per unit cross-sectional area A.

Simplified data for the applied force the ground withstands F, and the cross-sectional area A, are given in Fig. 7.3.

F / kN	A / m^2
922	4.3
916	4.4
936	4.5
958	4.6
980	4.7
996	4.8
1020	4.9
1040	5.0

Fig. 7.3

The variation with A of F is as shown in Fig. 7.4.

(i) Complete Fig. 7.4 by drawing the best-fit line (ignore any anomalous data). [1]

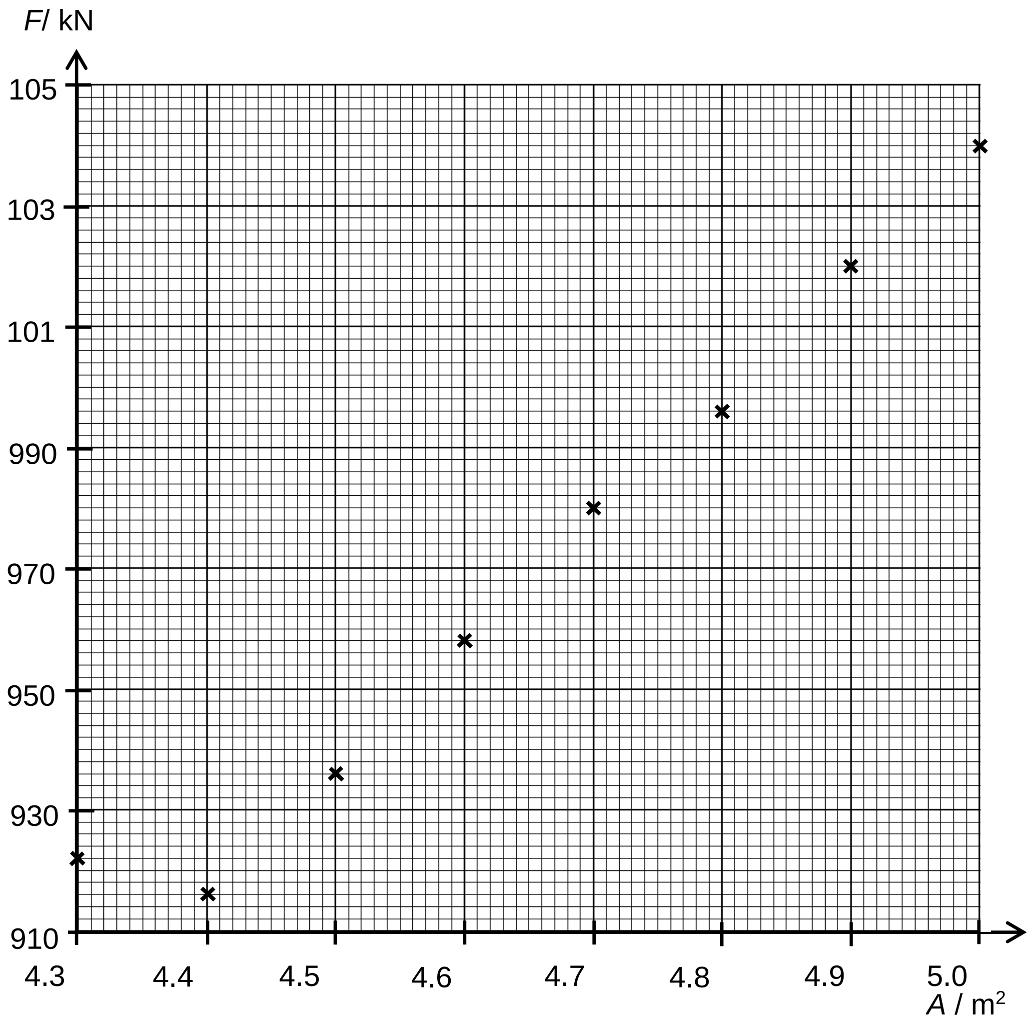

Fig. 7.4

(ii) Use Fig. 7.4 to determine the applied stress that the ground withstands.

applied stress = ……...….......……..... N m^{-2} [2]

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(iii) The column structure is considered safe if the factor of safety is greater than 2.9. Assuming that the maximum stress the ground is designed to withstand is 645 kN m^{-2}, determine whether the column structure is safe.

column structure is .... [2]

(e) The simplified dimensions of each column are given in Fig. 7.5.

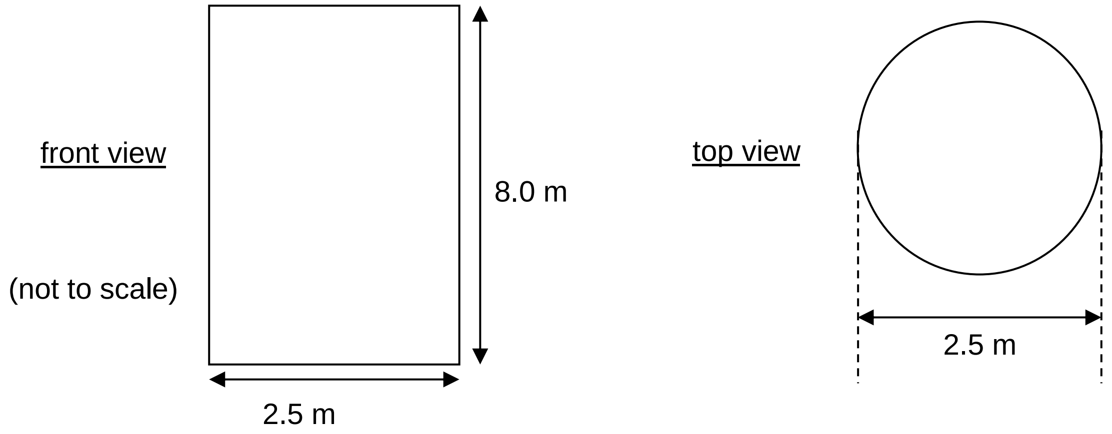

Fig. 7.5

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(i) Using the value of applied stress from **(d)(ii)**, calculate the applied load that the ground withstands.

applied load = ... N [2]

(ii) Hence using e(i) and c(iv), calculate the total allowable weight of passengers that each car can carry.

allowable weight = ... N [1]

(iii) Assuming the average mass of 1 passenger to be 60 kg and value of *g* to be 10 m s^{-2}, calculate the allowable number of passengers that a car can carry at any one time.

number of passengers = …………..….......……..... [2]

(f) A transport engineer is employed to design the frequency of the trains arriving at Tuas Crescent MRT Station. In order not to cause the ground to sink, he needs to look into the allowable passengers that each car can take and not overload each car. The following information is available to him:

<u>Peak hours at Tuas Crescent MRT Station</u>

Average number of east-bound passengers per minute = 240

On average, a typical east-bound train of 6 cars is anticipated to be already 75% filled just before it arrives at Tuas Crescent MRT Station.

Assuming that each car takes equal number of passengers and all board the train, determine the maximum time interval between arrival of consecutive east-bound trains at the station during peak hours.

Maximum time interval = …….…… minutes [3]