Site Investigation and Design of a Grade Separated Intersection in Harare, Zimbabwe

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Abstract. The aim of the paper is to design a grade separated intersection at Seke Road and Cripps/Dieppe Road in Harare, Zimbabwe. During the peak hours on weekdays, congestion and long queues occur at Seke Road and Cripps/Dieppe Roads intersection in Harare, Zimbabwe therefore there is need to improve this intersection. Significant traffic and congestion across urban areas creates a demand for grade separated intersections. The construction of these structures plays a critical role in the development of modern infrastructure due to safety, environmental, and economic reasons. With the increase in traffic there is need for an improved intersection. The scope of the work included an assessment of some of the intersections in Harare where grade separation is feasible, selection of one intersection, design of the grade separated intersection according to appropriate design standards and production of a bill of quantities. The project includes a traffic counting survey which was conducted for the purpose of determining the traffic volumes and hence the justification of upgrading the existing intersection. The methodology included production of a map, traffic counts, collection of secondary data on traffic counts, conducting geotechnical investigation tests and geometric and structural design of the intersection. Geotechnical investigation results were also used to determine the foundation depth of the bridge. The project contains literature of the different types of intersections, the advantages and disadvantages and also the different types of bridges. The traffic data was analysed and the most appropriate intersection design was chosen. The Simple Diamond interchange was designed because it is cost effective as it reduces congestion at Seke Road and Cripps/Dieppe Roads intersection. However the intersection should be further upgraded to a full clover leaf or a three level intersection within the next 20 years so as to avoid congestion again due to high traffic volumes. The interchange is a Simple Diamond interchange which was designed according to South African Standards. The analysis was carried out using Prokon Software, AchiCAD software, Microsoft word, AutoCAD and Microsoft word. A physical model was also made for the design. It is recommended that pre-stressed beams can be cast on the open space available and lifted by cranes to their positions and the grade separated intersection should have more columns for aesthetic reasons.

Keywords: Grade Separated Intersections, Congestion, Traffic Volumes, Geotechnical Investigation, Diamond Interchange and Bridges.

1 Introduction

1.1 Background

Significant traffic and congestion across urban areas creates a demand for grade separated intersections. The construction of these structures plays a critical role in the development of modern infrastructure due to safety, environmental, and economic reasons. A variety of grade separated intersection construction practices have been observed over the years in other countries. Planning, design and construction techniques are revised and refined to satisfy several parameters including feasibility, ease of construction, safety, maintainability, and economy. (Hueste, 2012). Figure 1 shows a photograph of the afternoon peak hour (from 1500 to 1700 hours) congestion at Seke Road/Cripps Road Intersection in Harare, Zimbabwe.

Figure 1 Afternoon peak hour congestion at Seke/Cripps Intersection in Harare, Zimbabwe

1.2 Problem Statement

During the peak hours on weekdays, congestion and long queues occur at Seke and Cripps/Dieppe intersection in Harare, Zimbabwe therefore there is need to improve this intersection. The intersection is situated in an industrial area with Coca Cola and National Tyre Services close by. It is used by people coming from the small town Chitungwiza going to the city centre and also people from the southern suburbs such as Sunningdale etc. Most people will be going to work and to school. The Cripps road leads to the Mutare road so buses use it when coming from the Mbare bus station going to Mutare.

With the increase in traffic there is need for an improved intersection. When the intersection was constructed it was supposed to serve certain traffic but now since there has been an increase in the number of vehicles passing through the intersection, it needs to be upgraded. An interchange is appropriate for this intersection since at-grade intersections can no longer accommodate the current traffic, let alone the future traffic. The most appropriate design has to be implemented for the intersection depending on the cost, availability of land and also the necessity of the interchange.

1.3 Justification of the Project

Intersections that must carry vehicles and pedestrians limit capacity of roads. Grade separating conflicts points at intersection allows an uninterrupted flow of traffic and minimizes accidents. Grade separated intersections are now a need as there is a vast traffic increase in Harare by each day. A good way of stopping conflicting intersection movements is placing the intersecting roads at different levels, or grade separating them. As most accidents now occur at intersections (Harare Traffic Department), it is best to come up with intersections that minimize accidents and yet are cost effective. Traffic is increasing every day in most cities and it is best to provide intersections that can meet the flow and yet are cost effective. According to Harare City Council traffic data, there was a 39% traffic increase in only four years at Seke and Cripps/Dieppe intersection and this is a huge increase hence the need to upgrade the intersection. The project involves identifying a suitable intersection and designing one.

1.4 Intersection analysis

The analysis considers both existing and future traffic. The morning peak hour is then critical peak, and is therefore considered for analysis.

The following scenarios are considered during the morning peak hour:

1. The current intersection as robot controlled cross junction.
2. A roundabout
3. A diamond interchange

The current intersection is no longer adequate for the traffic volumes and also there is no space for a roundabout hence a diamond interchange should be designed for the intersection. (O'Flaherty, 1986)

The economic evaluation of the project compares the benefits and costing of retaining the existing Seke and Cripps/Dieppe intersection unaltered versus the improvement of traffic operation through the construction of a diamond interchange.

For this intersection the option considered is the interchange alternative.

2 Literature Review

2.1 What is an Intersection?

An intersection is the area shared by the joining or crossing of two or more roads. (Stollof, 2008). It is a place, where roads intersect or connect in the horizontal projection and minimally two roads are joined (united) together. Intersection provides passage of vehicles (crossing) from one road to other one (Mary Beth D. Hueste, 2012).American Association of State Highway and Transportation Officials (AASHTO) defines intersection as the general area where two or more roadways join or cross and is defined by both its functional and its physical areas. The functional area of an intersection extends both upstream and downstream from the physical intersection area and includes auxiliary lanes and their associated channelization. (Stollof, 2008). Intersections are designed so that vehicles are able turn to different directions so as to reach their destinations. The study of intersections is very important for traffic engineers because the traffic flow depends on road capacity and also on the performance of the intersection.(Rao, 2006).

2.2 Intersections are classified according to:

- Number of conflict points

- Traffic control
- Geometry : T shaped, Y shaped, Multi-leg

The different types of intersections are shown in Figure 2.

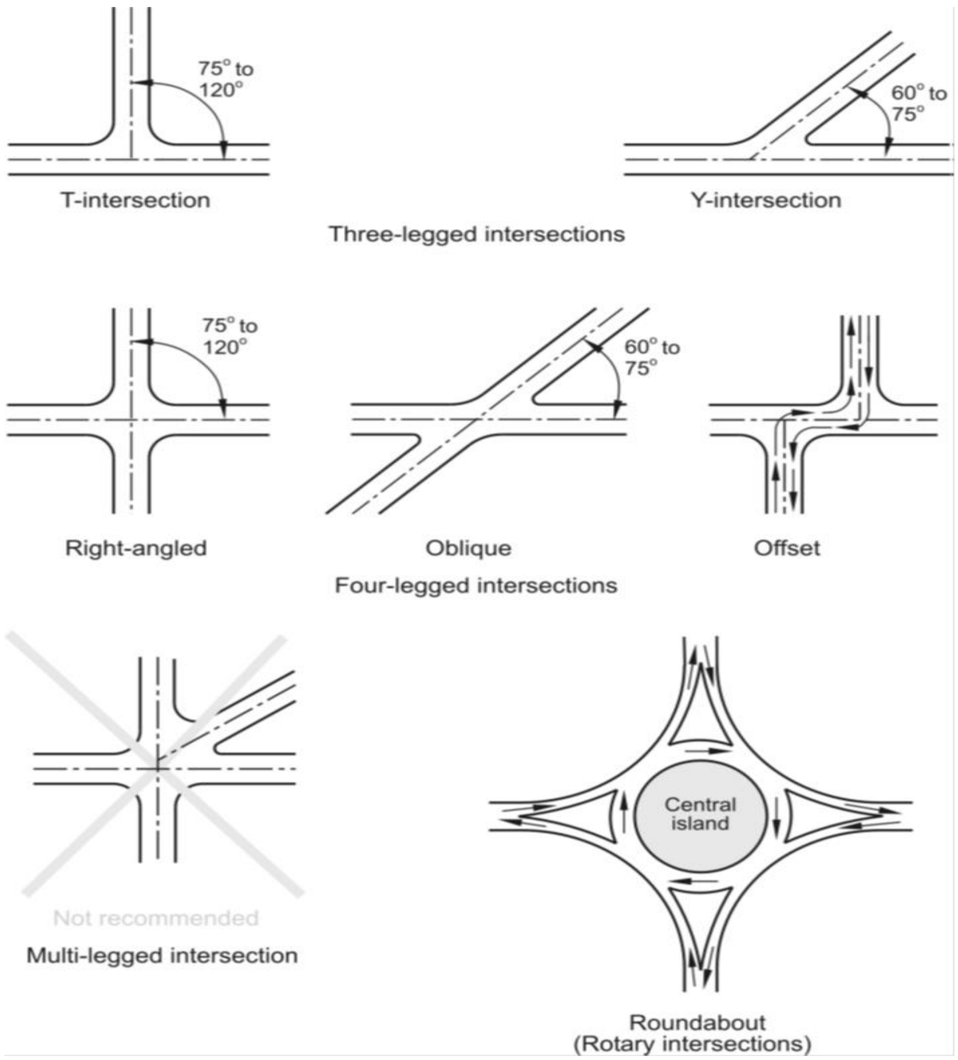

Figure 2 Types of intersections (Source: Geometric Design Guide, South African National Roads Agency 2006, Chapter 6: Intersection Design

2.2.1 Conflicts at an Intersection

Intersections have different conflicts depending on the type of intersection. The four-legged intersection shown in Fig 3 has thirty-two different types of conflicts. The number of conflicts for competing through movements is four, while competing right turn and through movements is eight. The conflicts between right turn traffics are four, and between left turn and merging traffic are four. The conflicts created by pedestrians are eight and also diverging traffic produces four conflicts. (Salter, 1989).

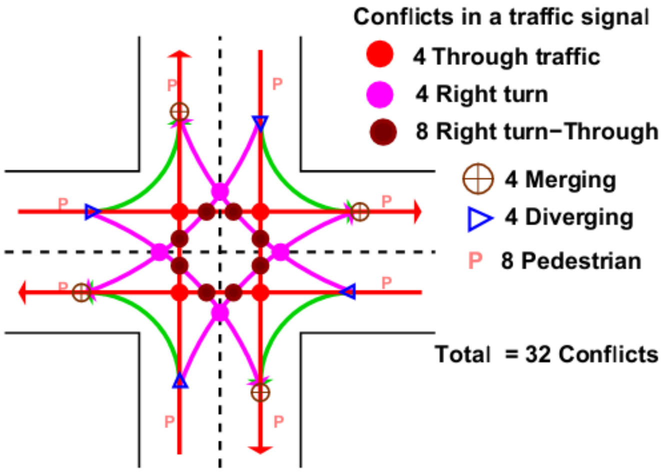

Figure 3 Intersection Conflicts. Source: (Salter, 1989)

a) Priority intersections

Priority intersections are intersections where traffic flow from the minor road gives way to traffic on the main highway, and only enters the major road done when a sufficient gap is available. There are two classes of priority intersections which are: simple intersections which have no signs and controlled intersections with signs. (O'Flaherty, 1986)

b) Uncontrolled intersections

Uncontrolled intersections are not used in conjunction with the main road network, but are common in rural networks and access roads to rural settlements. In these cases, drivers must be able to see potentially conflicting vehicles on intersecting approaches in sufficient time to stop safely before reaching the intersection. Ideally, sight triangles with legs equal to stopping sight distance should be provided on all the approaches to uncontrolled intersections.

Major/minor priority junctions are the most common form of junction control. Traffic on the minor road gives way to traffic on the major road and is normally controlled by "Give Way" signs and road markings. (Administration, 2013).

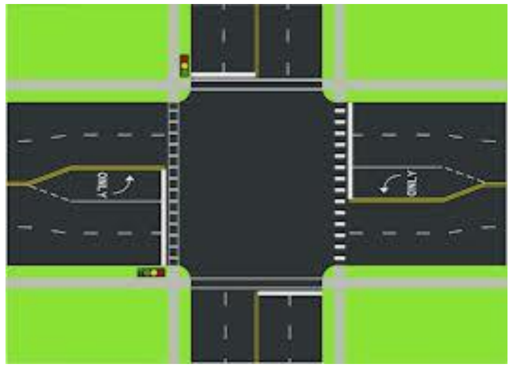

Figure 4 Give way Intersection (Administration, 2013)

2.2.2 Roundabout Intersections

Delays at roundabouts are usually less than at conventional intersections and, in consequence, capacity is higher. The proviso is that the combined intersection flow should be less than 3 500 veh/h. Reduced delays improve vehicle operating costs. Roundabouts have less potential conflict points than conventional intersections. In the case of the four-legged intersection, 32 conflict points are replaced by 8. In both roundabouts and conventional intersections, the diverge is also counted as being a conflict point. The safety performance of roundabouts is often superior to that of most conventional intersections and the reduced number of conflict points at roundabouts result in an observable reduction in accident rates.

Roundabouts can be considered when:

1) Intersection volumes do not exceed 3 000 veh/h at three-legged or 4 000 veh/h at four-legged intersections;
2) The proportional split between the volumes on the major and minor road does not exceed 70/30;
3) Where, on three-legged intersections, the intersection flow is less than 1 500 veh/h or,
4) On four-legged intersections, is less than 2 000 veh/h. (Salter, 1996).

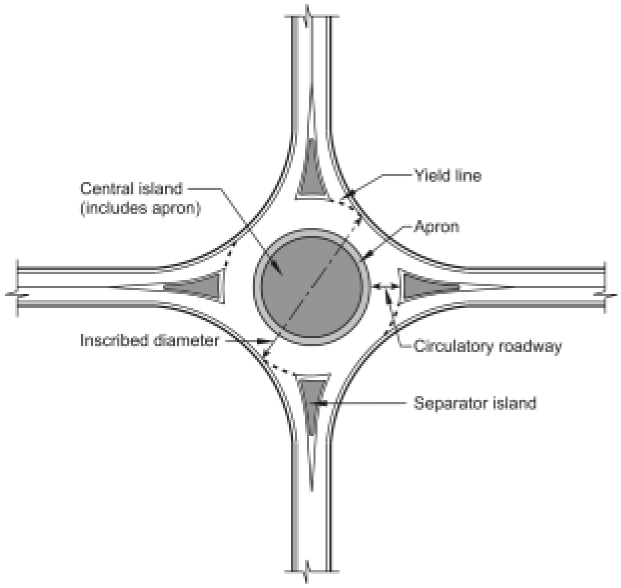

Figure 5 Roundabout Layout (Mass Highway 2006: Chapter 6, Intersection Design)

2.2.3 Signal controlled intersections

In general, approach or departure sight triangles are not needed for signalized intersections. Indeed, signalization may be an appropriate accident countermeasure for higher volume intersections with restricted sight distance and a history of sight-distance related accidents. However, traffic signals may fail from time to time. Furthermore, traffic signals at an intersection are sometimes placed on two-way flashing operation under off-peak or night time conditions. (South African Geometric Design Guidelines, 2006).

Figure 6 Signal Controlled Intersection (Administration, 2013)

2.3 Interchanges

These are intersections where conflicts are resolved or reduced by introducing a vertical separation between the different traffic movements. The complexity of the layout of an interchange may vary from separation of the through flows only, with turning taking place at the level of the lesser movement, to the separation of all the movements. The difference between interchanges and other forms of intersection is that, in interchanges, crossing movements are separated in space, whereas in other intersections (at-grade), they are separated in time.

Also, the turning movements at interchanges are accommodated on ramps whereas at-grade intersections accommodate turning movements either within the limitations of the crossing roadway widths or through the application of turning roadways. A more effective interchange will be produced by considering the individual movements and the traffic volumes associated with each, and building up the layout. (South African Geometric Design Guidelines, 2006)

2.3.1 Interchange types

There is a wide variety of types of interchanges that can be employed under the various circumstances that warrant the application of inter-changes. The major determinant of the type of interchange to be employed at any particular site is the classification and characteristics of the intersecting road. Intersecting roads are typically freeways or urban arterials but may also be collectors. In the case of freeways as intersecting roads, reference is made to systems interchanges. Systems interchanges exclusively serve vehicles that are already on the freeway system. Access to the freeway system from the surrounding area is via interchanges on roads other than freeways, for which reason these interchanges are known as access interchanges. Service areas, providing opportunities to buy fuel, or food or simply to relax for a while can typically accessed via an interchange.

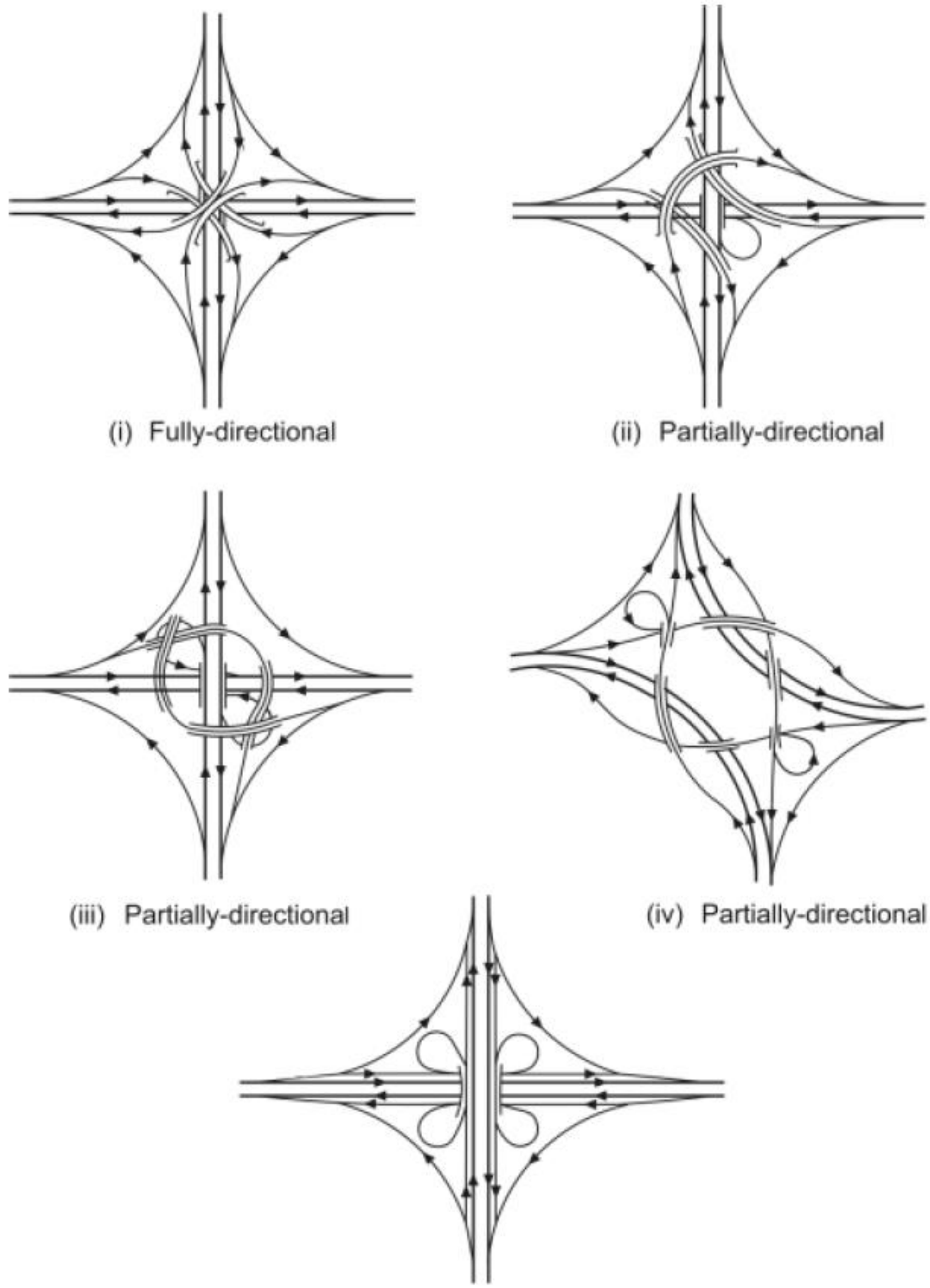

Figure 7 Four legged intersections (Source: Geometric Design Guide, South African National Roads Agency 2006, Chapter 6: Intersection Design)

3. Intersection Analysis

The intersection is the Seke and Cripps/Dieppe intersection. The intersection is a signal controlled intersection that is approximately 2.6km to the south of the Harare City Centre and is shown in Figure 8. The intersection is a four leg intersection with the following legs: The Seke towards town forms the south leg; The Seke towards Chitungwiza forms the north leg; The Cripps towards Braeside forms the west leg and The Cripps towards Mbare forms the south leg.

Figure 8 Intersection under consideration (Google Earth)

The street map for Harare shows the roads and intersections. The intersection under consideration is highlighted in red and is shown in Figure 9.

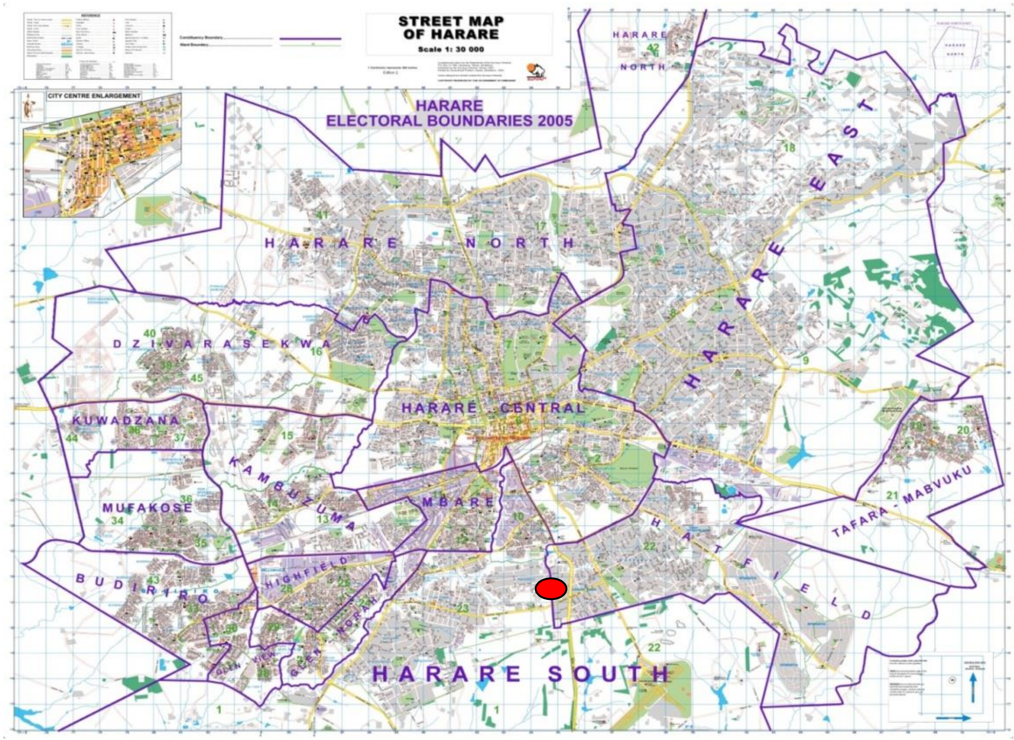

Figure 9 Harare Street Map

Some of the intersections where grade separation is feasible are: Robert Mugabe and Airport/Enterprise intersection; Airport and Dieppe intersection; Airport and George intersection and Julius Nyerere and Kenneth Kaunda intersection.

3.1 Traffic Volumes

Table 1: Traffic Volume veh/hr/two lanes

TIME	THROUGH TRAFFIC				RIGHT TURNING TRAFFIC				LEFT TURNING TRAFFIC			
	LIGHT VEH	MINIBUSE	BUSES	HEAVY VEH	LIGHT VEH	MINIBUSES	BUSES	HEAVY V	LIGHT VEH	MINIBUSES	BUSES	HEAVY VEH
7:00												
7:05	65	35	4	2	28	0	0	5	15	2	0	1
7:10	74	24	2	8	16	1	0	3	11	2	0	2
7:15	56	30	0	4	23	2	0	3	24	1	0	4
7:20	70	26	0	3	21	0	0	2	14	4	1	2
7:25	61	33	1	1	20	0	0	3	30	5	0	3
7:30	55	27	1	6	21	0	0	4	16	4	0	2
7:35	68	36	2	3	26	0	0	3	18	3	1	2
7:40	69	26	1	7	16	1	0	2	10	1	0	3
7:45	66	24	2	2	22	1	0	5	22	2	0	2
7:50	60	25	0	4	20	1	0	2	15	5	0	2
7:55	65	37	2	4	23	0	0	2	27	2	0	4
8:00	53	27	1	4	22	0	0	6	18	5	0	1
Total	**762**	**350**	**16**	**48**	**258**	**6**	**0**	**40**	**220**	**36**	**2**	**28**

Table 2 Traffic Volume pcu/hr/two lanes

TIME	THROUGH TRAFFIC				RIGHT TURNING TRAFFIC				LEFT TURNING TRAFFIC				TOTAL
	LIGHT VEH	MINIBUSE	BUSES	HEAVY VEH	LIGHT VEH	MINIBUSES	BUSES	HEAVY V	LIGHT VEH	MINIBUSES	BUSES	HEAVY VEH	
7:00													
7:05	65	52.5	8	4	28	0	0	10	15	3	0	2	187.5
7:10	74	36	4	16	16	1.5	0	6	11	3	0	4	171.5
7:15	56	45	0	8	23	3	0	6	24	1.5	0	8	174.5
7:20	70	39	0	6	21	0	0	4	14	6	2	4	166
7:25	61	49.5	2	2	20	0	0	6	30	7.5	0	6	184
7:30	55	40.5	2	12	21	0	0	8	16	6	0	4	164.5
7:35	68	54	4	6	26	0	0	6	18	4.5	2	4	192.5
7:40	69	39	2	14	16	1.5	0	4	10	1.5	0	6	163
7:45	66	36	4	4	22	1.5	0	10	22	3	0	4	172.5
7:50	60	37.5	0	8	20	1.5	0	4	15	7.5	0	4	157.5
7:55	65	55.5	4	8	23	0	0	4	27	3	0	8	197.5
8:00	53	40.5	2	8	22	0	0	12	18	7.5	0	2	165
Total	**762**	**525**	**32**	**96**	**258**	**9**	**0**	**80**	**220**	**54**	**4**	**56**	**2096**

3.2 Elevations

The elevations gives the height above sea level in metres. The elevations of the area around the intersection were taken so as to see if the ground is level, rolling or mountaneous. Tables 3 and 4 gives the distance from the existing intersection and the elevations with the East direction being positive. Figure 3.2 shows the elvations.

Cripps/Dieppe Road

Table 3 Elevations along Cripps/Dieppe Road

Distance (m)	Elevation (m)
0	1468
-90	1468
-150	1469
120	1469
150	1469

Seke Road

Table 4 Elevations along Seke Road

Distance (m)	Elevation (m)
0	1468
-7	1469
-42	1470
-70	1471
-100	1472
-130	1473
-165	1474
-190	1475
35	1467
180	1469
250	1469

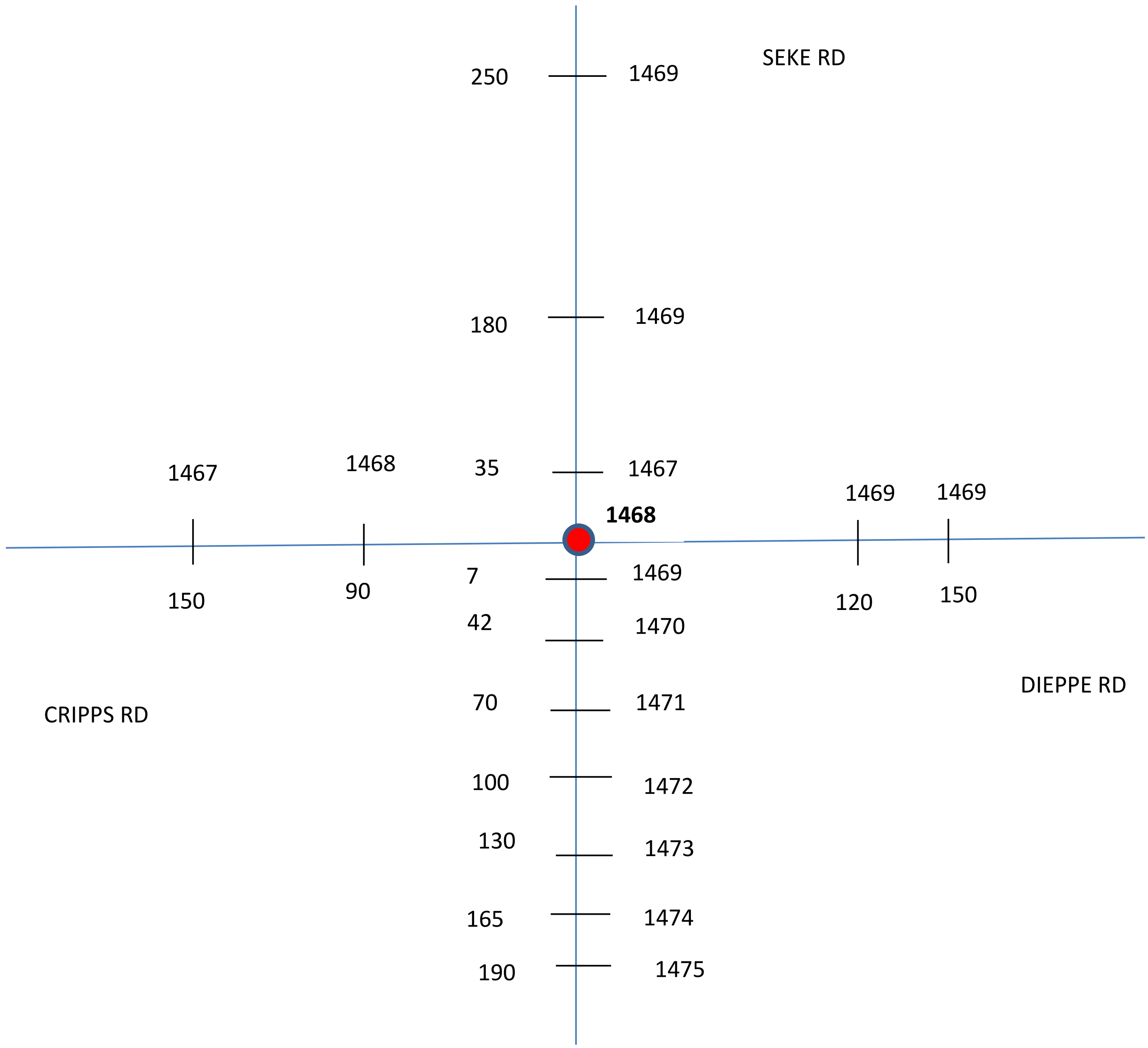

Figure 10 Elevations

4. Analysis of Results

The counting survey was done From Monday 16 December 2013 to Friday 20 December during the peak hours: morning peak hour (7-8am), afternoon peak hour (12.30-1.30pm) and evening peak hour (4.30-5.30pm). The counting was done for all the twelve traffic movements i.e. through vehicles, left turning vehicles and right turning vehicles.The data was recorded according to the type of vehicles. The four categories used are: small vehicles, commuter omnibuses, ordinary buses and heavy vehicles. The traffic data for 2009 and 2012 was obtained from the Harare City Council and was also used for analysis so as to predict the future traffic increase. The data is shown in Appendix A. The traffic was converted into pcu's using the equivalency factor of 2 for buses and heavy vehicles, and 1.5 for commuter omnibuses. (South African Geometric Design Guidelines, 2006).

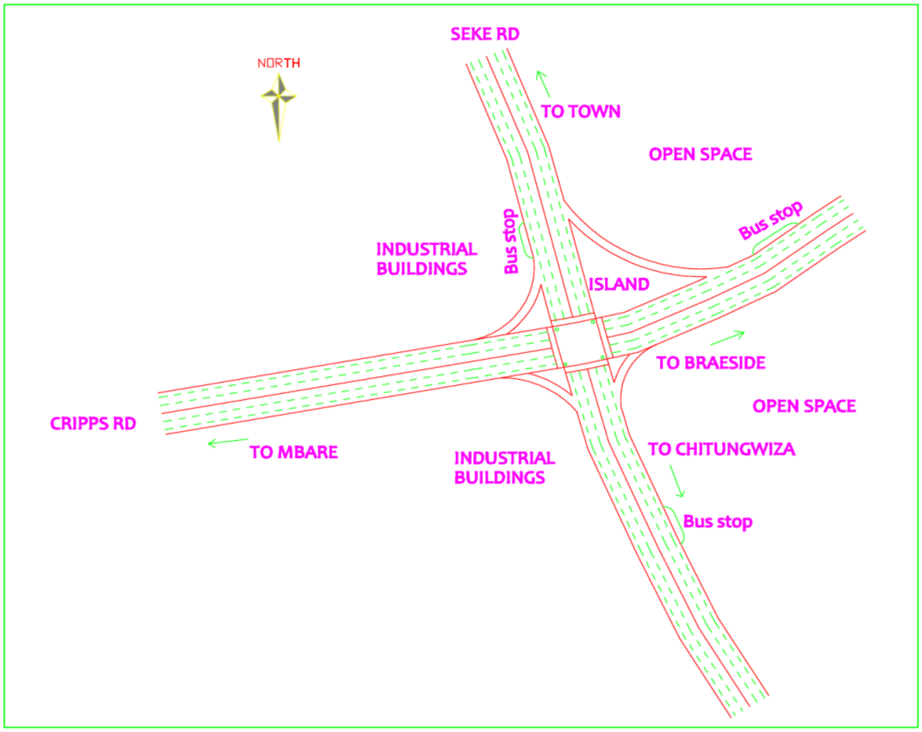

Figure 11 Seke and Cripps/Dieppe Intersection

4.1 Traffic Data

4.1.1 Historical Data

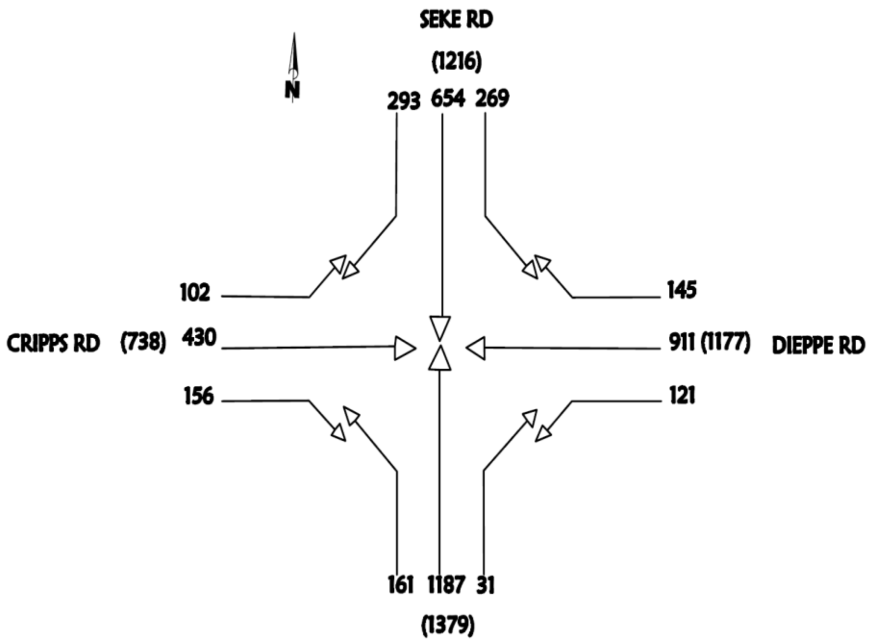

Figure 12 Traffic counts on a Monday morning 2009, Source: Harare City Council

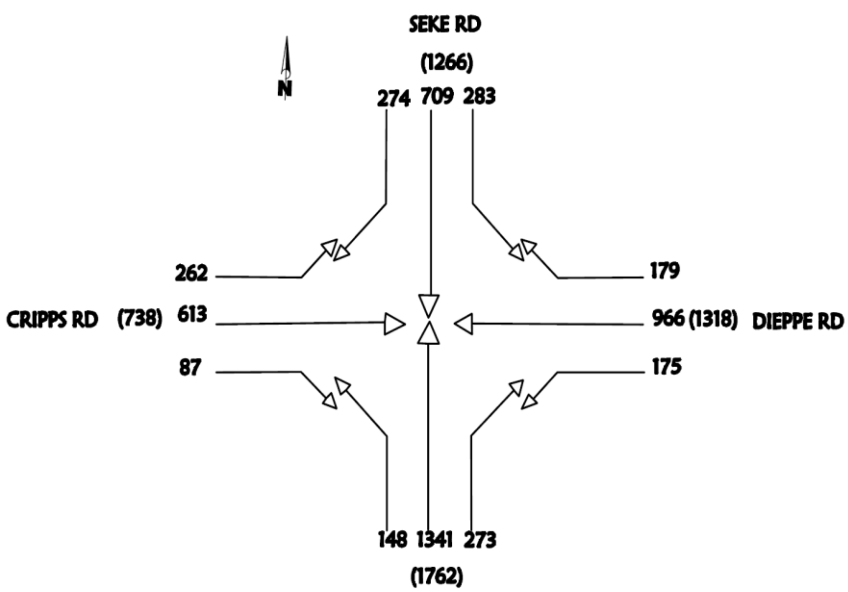

Figure 13 Traffic counts on a Monday morning 2012, Source: Harare City Council

4.2 Existing Traffic Volumes

4.2.1 Traffic Counts

To supplement historic traffic data, new traffic counts were carried out at the intersection to determine the 2013 base traffic volumes. This consisted of the peak hour traffic counts conducted on Monday the 16th of December 2013 in pcu/hr.

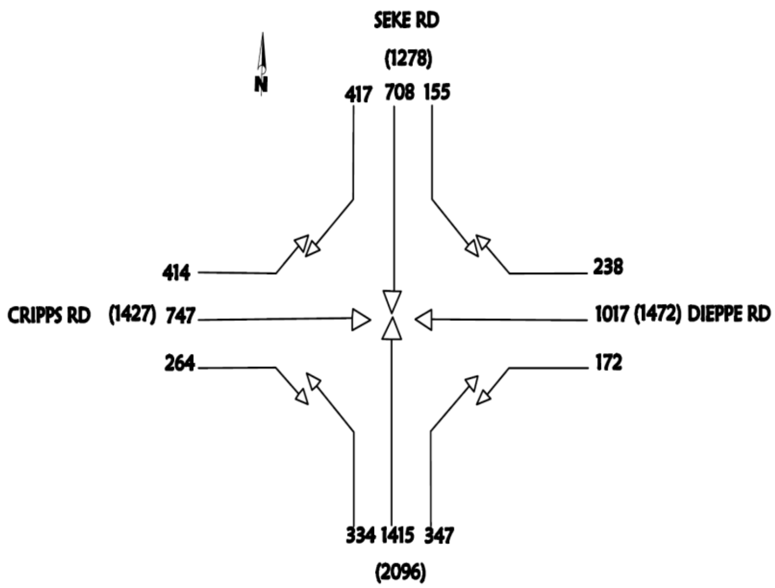

Figure 14 Traffic counts on a Monday Morning 2013

4.3 Traffic Conditions

The two roads (Seke and Cripps/Dieppe), are two-way two-lane roads. During the morning peak hour, the southern approach is the most trafficked link with a total of 2096 vehicle per hour whilst the western approach is the least trafficked with 1427 vehicles per hour. The south to north movement is predominant. Long queues and delays are therefore the main problem during all peak hours.

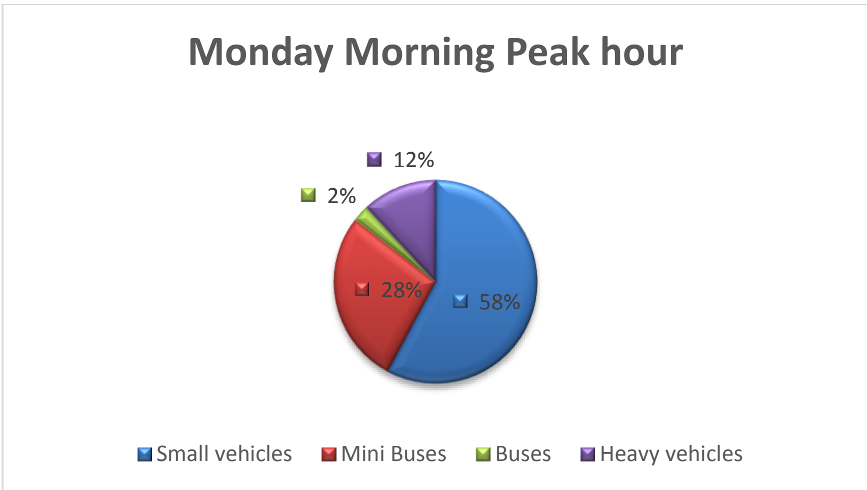

Figure 15 Traffic distribution

4.4 Future Traffic Volumes

Traffic Growth

Analyzing for the morning peak hours on the basis of existing traffic counts:
Total traffic for 2013 = 6273pcu/hr
Total traffic for 2012 = 5308pcu/hr
Total traffic for 2009 = 4510pcu/hr

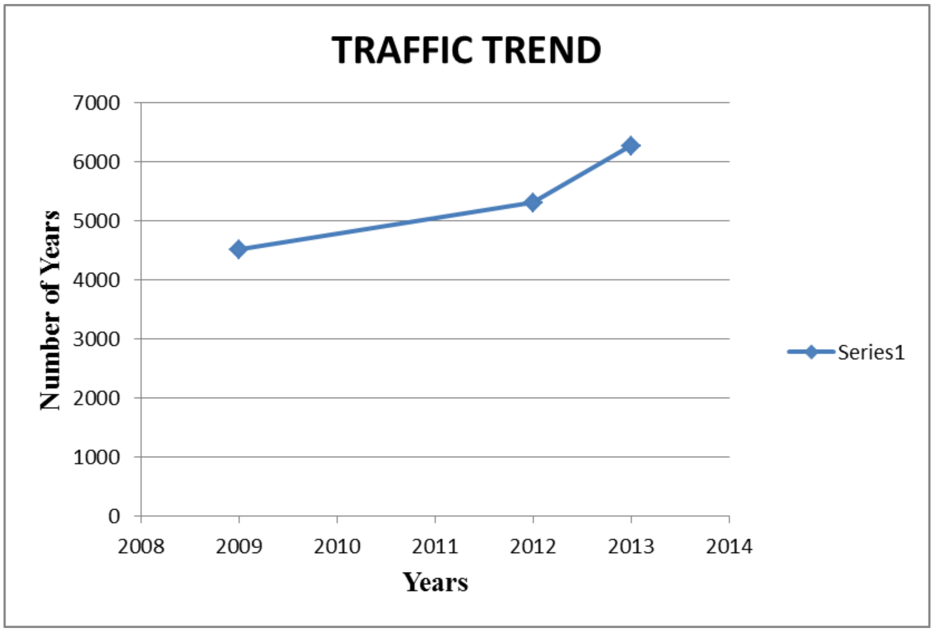

Figure 17 Traffic Trend at Seke/ Cripps Roads Intersection

4.5 Geotechnical Investigations

The geotechnical investigations are based on the data obtained from the Harare City Council. The DCP test was carried out so as to obtain the level with safe bearing capacity for the foundation design of the bridge abutments

4.5.1 Bridge Foundation Investigations and Design Bearing Capacities
The locations of the bridge abutments were investigated for suitability for the use of normal reinforced concrete raft type footings by carrying out a Dynamic Cone Penetrometer (DCP) Survey and the excavation and logging of Trial Holes to a depth of about 2.5 metres. The initial survey was carried out by recording penetration depths from ground level to a depth of 1 metre (the length of the DCP shaft). Trail holes were then excavated to this depth and penetrometer testing continued. Excavation continued to 1.5 metres below ground level and DCP testing to a depth of about 2.5 metres completed.

On study of the results the survey was extended by excavating trial pits to a depth of 2.5 metres (the extent of the initial testing) and penetrometer testing continued below this level where practicable. Results were reduced to tables of penetration per blow and safe bearing capacities extrapolated using the correlation curves recommended by the Transport & Road Research Laboratory (TRRL UK) now the Transport Road Laboratory (TRL). These correlations are reproduced in the Mote Bridge Design Manual (1985).

4.5.2 Evaluation of Depths to Safe Bearing Capacity

The results of the DCP survey were plotted graphically against depth below ground level at each site. Study of these graphs suggested the minimum depths at which the footing should be founded. In all cases it is proposed that the top of all RC footings be a minimum of 500mm below ground level (1 500 to underside of footing).

4.5.3 Typical DCP plot

Plot shows Safe Bearing Capacity of 200 kN/m^2 at level 100 equivalent to a depth below ground level of 2.6 metres.

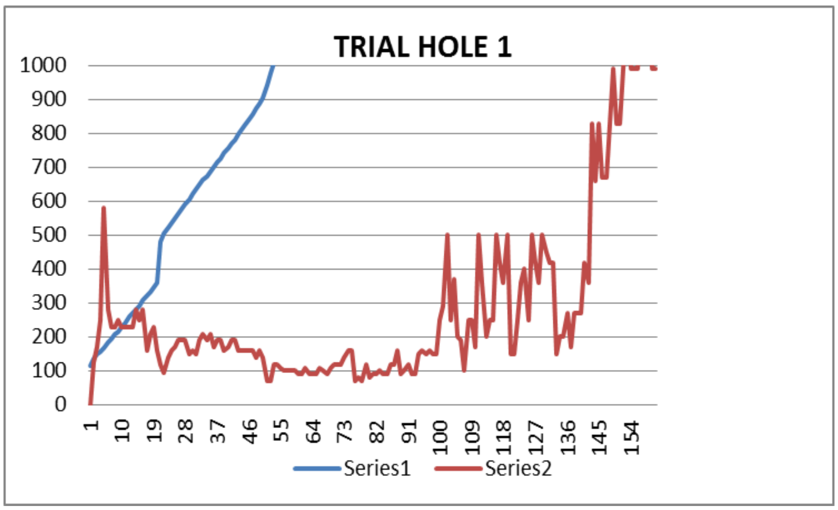

Figure 18 DCP Plot (Source: Harare City Council)

4.5.4 Geology of the Site

The geology of the Greater Harare area is granite and gneiss and the pedalogy comprises residual soils of the underlying granite rock. Rainfall is moderate to high with the mean annual rainfall varying from 600 to 800 mm.

4.5.5 Soils around the intersection

The area around the intersection comprises silty clays of medium to high plasticity interspersed with sandy clays of medium plasticity. These soils are typical of the pedology of the area and reflect some areas of poor drainage. Underlying this horizon the leached soils tend to be more plastic.

4.5.6 Safe Bearing Capacity

The extrapolated values of SBC are for design pressures at Serviceability Limit State and by inspection a design bearing capacity of 200 kN/m^2 is considered appropriate at all bridge sites.

Spread footings for all the bridge structures may be employed. The minimum depth of footings should be 500 mm below ground level corresponding to a depth of 1 500 mm to underside of footing. The maximum depth for founding is 2 600 mm. A DCP survey should be performed at each excavation to confirm that a safe bearing capacity of at least 200 kN/m^2 corresponding to a DCP penetration of not more than 12 mm/blow, is obtained at founding level. If excavation to a greater depth is required in order to meet this criterion then mass concrete stoolings should be provided below the footing. The stooling should be battered at a slope of 1 horizontal to 5 vertical on the front face and the depth limited to 1 500 mm.

5 Intersection Design

The intersection was designed according to South African Standards. The South African Geometric Design Guidelines (2006) was used.

A gradient of 4% was used and the bridge is 6m from the ground (minimum is 5,1m according to The South African Geometric Design Guidelines).

5.1 Horizontal Alignment Design

5.1.1 Circular curves

A circular curve is shown in Fig 5.1. The figure shows a wholly circular curve and its components.

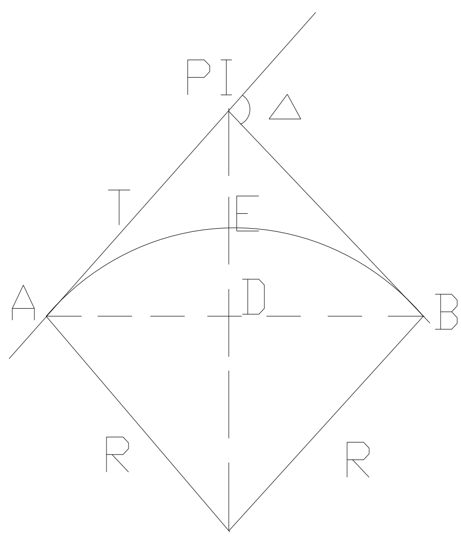

Figure 20 Wholly circular curve

Where: R= radius of the curve

Δ= deflection angle

PI= point of intersection

Equation 1 Formula for Tangent length

$$T = R.tan\ (\Delta/2)$$

Equation 2 Formula for Long chord length

$$C = 2.R.sin\ (\Delta/2)$$

Equation 3 Formula for Length of curve

$$L = R\Delta\ (\frac{\pi}{180})$$

Equation 4 Formula for Middle ordinate distance

$$DE = R\ [1 - cos\ (\Delta/2)]$$

Equation 5 Formula for External distance

$$EPI = R\ [sec\ (\Delta/2) - 1]$$ (Salter, 1989)

5.1.2 Design of horizontal curve 1

The curve is wholly circular curve with design speed 80mk/hr.

Radius of curve =143m

Deflection angle Δ=78^0

Tangent length $T = R.tan\ (^{\Delta}/_{2}) = 143 * tan\ \left(\frac{78}{2}\right) = 116m$(Equation 1)

Length of circular curve $L = R.\Delta.(\frac{\pi}{180}) = 143 * 78 * \left(\frac{\pi}{180}\right) = 195m$(Equation 3)

Chord length $C = 2R\ Sin\ 390 = 180m$ (Equation 2)

Chainage at BCC 2+445m

Chainage at ECC 2+640m

Table 5: Setting out for horizontal curve 1

POINT	LENGTH	CHAINAGE	DEFLECTION	CUMMULATIVE ANGLE	DISTANCE FROM BCC
BCC	0	2+445	0	0	0
P1	15	2+460	3˚ 0’ 18.0842’’	3˚ 0’ 18.0842’’	15
P2	20	2+480	4˚ 0’ 24.1123’’	7˚ 0’ 42.1966’’	35
P3	20	2+500	4˚ 0’ 24.1123’’	11˚ 1’ 6.3089’’	55
P4	20	2+520	4˚ 0’ 24.1123’’	15˚ 1’ 30.421’’	75

P5	**20**	**2+540**	**4˚ 0’ 24.1123’’**	**19˚ 1’ 54.534’’**	**95**
P6	**20**	**2+560**	**4˚ 0’ 24.1123’’**	**23˚ 2’ 18.646’’**	**115**
P7	**20**	**2+580**	**4˚ 0’ 24.1123’’**	**27˚ 2’ 42.758’’**	**135**
P8	**20**	**2+600**	**4˚ 0’ 24.1123’’**	**31˚ 3’ 6.8705’’**	**155**
P9	**20**	**2+620**	**4˚ 0’ 24.1123’’**	**35˚ 3’ 30.983’’**	**175**
ECC	**20**	**2+640**	**4˚ 0’ 24.1123’’**	**39˚ 3’ 55.095’’**	**195**

5.1.3 Design of horizontal curve 2

The curve is wholly circular curve with design speed 80mk/hr

Radius of curve =274m

Deflection angle Δ=46^0

Tangent length

$T = R.tan\ (\ \Delta\ /\ 2) \quad = 274 * tan\ (46/2)\ =\ 116m$ (Equation 1)

Length of circular curve $L = R.\Delta.(\pi/180) \quad = 274 * 46\ * (\pi/180) = 220m$ (Equation 3)

Chord length $C = 2R\ Sin\ 23\ = 214m$ (Equation 2)

Chainage at BCC 2+550m

Chainage at ECC 2+ 770m

Initial deflection angle = (10* 180)/(2*274*π) = 1˚2’43.9563”

Final deflection angle = (10 *180)/(2*274*π) = 1˚2’43.9563”

Using a chain age of 40m

Table 6 Setting out for horizontal curve 2

POINT	LENGTH	CHAINAGE	DEFLECTION	CUMMULAIVE ANGLE	DISTANCE FROM BC
B C	0	2550	0	0	0
P1	10	2560	1˚ 2’ 43.9563’’	1˚ 2’ 43.9563’’	10
P2	40	2600	4˚ 10’ 55.825’’	5˚13’ 39.782’’	50
P3	40	2640	4˚ 10’ 55.825’’	9˚ 24’ 35.607’’	90
P4	40	2680	4˚ 10’ 55.825’’	13˚ 35’31.43’’	130
P5	40	2720	4˚ 10’ 55.825’’	17˚ 46’ 27.26’’	170
P6	40	2760	4˚ 10’ 55.825’’	21˚ 57’ 23.08’’	210
ECC	10	2770	1˚ 2’ 43.9563’’	23˚ 0’ 7.039’’	220

The ground level is almost level hence no vertical alignment design was carried out.

5.2 Design Calculations Of The Bridge

The calculations were done using Prokon software and also by hand.

5.3 Bill of Quantities

The bill of quantities is shown in Table 7.

Table 7 Bill of Quantities for the project

ITEM	DESCRIPTION	AMOUNT ($)
1	Road formation	7,097.21
2	Pavement works	12880.92
3	Surfacing	30474.93
4	Detours	100,700.00
5	Accommodation vehicles and equipment	65,000.00
6	Falsework, formwork and concrete finish	62,050.00
7	Steel reinforcement for structures	141,000.00
8	Concrete for structures	249,700.00
9	No-Fines concrete, drainage etc.	56,635.00
10	Provisional sums	800,000.00
	TOTAL	**1,525,538.06**

6.0 CONCLUSION

The Simple Diamond interchange is cost effective as it reduces congestion at Seke and Cripps/Dieppe intersection. However the intersection should be further upgraded to a full clover leaf or a three level intersection within the next 20 years so as to avoid congestion again due to high traffic volumes.

6.1 RECOMMENDATIONS

Traffic should be diverted and extra caution should be taken during the construction since the area is an industrial area. The pre-stressed beams can be cast on the open space available and lifted by cranes to their positions. The grade separated intersection should have more columns for aesthetic reasons. Proper site investigations should be done including survey so as to come up with the road levels. Also the drainage system should be designed and the retaining wall for the rising road.

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