TRUCK USE OF NEWLY-INSTALLED ROUNDABOUTS ON THE KUMASI–EJISU SECTION OF THE ACCRA–KUMASI–GONOKROM ROAD (ROUTE N6)

by

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CERTIFICATION

I hereby declare that this submission is my own work towards the MSc and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

Truck use of four newly-installed roundabouts on a rehabilitated section of Route N6 in Ghana was investigated. The study was motivated by public opposition to the roundabouts as a result of the occurrence of a number of accidents, particularly truck accidents, shortly after the rehabilitated section had been opened to traffic. The study involved observation of truck driver manoeuvres at the roundabouts, interview on truck driver knowledge of use of the device, and review of the accident records for as well as the as-built drawings of the roundabouts. Of a total of 16 accidents that have occurred to date since the installation, seven (46.7%) involved trucks with all the truck accidents taking place only at a particular roundabout (the University Police Station Roundabout). Of the seven truck accidents, five involved vehicle rollover (overturning). A comparison of the accident records at the intersections before and after conversion to roundabouts did not point to deterioration in safety following conversion except for the intersection at the University Police Station where the reverse was the case. Of 240 truck drivers interviewed who use the route, none knew the essence of the truck apron forming part of the roundabouts as they all considered tracking the apron a traffic offence and as many as 185 (77.1%) said they never use the apron. This perception was well corroborated by the results of the truck manoeuvre study at one of the roundabouts in which 150 (80.2%) of the 187 trucks captured on video manoeuvred the roundabouts in such a way as to avoid tracking the apron. All the drivers interviewed admitted that avoiding the truck apron made manoeuvring the roundabouts very difficult as it required extra caution especially when their vehicles carried load because of the possibility of load shifting. No

significant differences existed between the roundabouts in terms of geometric details except that the topography at the location of the roundabout with the highest accident record was relatively steeper than that at the other roundabout locations. It is believed that the high incidence of truck overturning accidents at the University Police Station Roundabout could be attributed to a combination of a possible vehicle imbalance caused by load shifting as the truck drivers manoeuvred to avoid tracking the truck apron and the unfavorable gradient at that roundabout. The installation of the roundabouts should have been preceded by elaborate driver education on how to use the device.

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1 INTRODUCTION

1.1 Background

The Accra–Kumasi–Gonorkrom Road, classified by the Ghana Highway Authority as Route N6, is one of the major roads in Ghana of international importance within the West African sub–region as it forms a vital link between Ghana and La Cote d'Ivoire as well as other countries beyond. In particular, it forms part of the trade route of a number of landlocked West African countries using the port facilities in Ghana for trans–shipment of freight. Since the beginning of the political conflict in La Cote d'Ivoire in 2003, Route N6 has come under increased use by heavy–goods vehicles (HGVs) as a number of the landlocked neighbouring countries, which hitherto had been using the port facilities in Abidjan, have now diverted to the use of the port facilities in Ghana for obvious reasons. To improve safety and traffic flow on the route, a 50km section of the road leading to the Kumasi Metropolis approaching from Accra was recently rehabilitated with a grant from the Danish government.

To ease congestion on the approaches to the metropolis, a 12.4km portion of the section leading to the metropolis was redesigned as a four lane divided highway. As part of the rehabilitation, four intersections within and abutting the metropolis were redesigned as roundabouts. A roundabout is a circular intersection joining two or more roads with traffic from the intersecting roads feeding into a "circulatory roadway" that surrounds a central island. The first roundabout on the section, travelling away from the Kumasi Metropolis in the direction of Accra, is located adjacent to the Kwame Nkrumah University of Science and Technology (KNUST)

Police Station, it replaced a four-legged intersection formed by a minor road from the university which crosses Route N6. The second, located at the intersection of Route N6 and the Boadi Road and the third at the intersection of Route N6 and the Anwomaso Road both replaced intersections which were originally T–intersections. The fourth, located within the Ejisu township, also replaced a four legged intersection. At each of the four roundabouts, the minor road approaches are single carriageways designed with splitter islands to separate entering and exiting traffic while the major road approaches have two lanes at each entry. Due to right–of–way restrictions at the location of the intersections, the roundabouts were all designed as single-lane. To prevent the two streams of traffic from each of the major road approaches from entering the single-lane roundabout, the outer lanes at each of the approaches have been gradually eliminated by the use of a flared cobbled island as the roundabout is approached so that vehicles enter and exit the roundabout only in a single stream using the inner lane. This design arrangement reverses at the major road exists so that exiting vehicles can separate into two streams as they move away from the roundabout.

Today's roundabouts termed "modern roundabouts" differ substantially from the large radii roundabouts built in the past which have fallen out of favour with design engineers because of safety and operational problems. Such large roundabouts technically called "traffic circles" achieved very little speed reduction due to the large radius of the circulatory roadway resulting in very little path deflection. In Ghana, one of such large roundabouts was the Tetteh Quarshie Roundabout (now replaced by an interchange) which was about 2km in circumference for the circulatory roadway.

The design of modern roundabouts is guided by the optimal balance between safety provisions, operational performance and large vehicle accommodation. To this end, during design, vehicles with large turning radii such as trucks, buses, and tractor – trailers (articulated trucks), are accommodated by the inclusion of a mountable area between the circulatory roadway and the central island, known as truck apron, over which the rear wheels of such vehicles can safely track. The truck apron generally is composed of a different material texture than the paved surface, such as brick or cobbled stones, to discourage routine use by smaller vehicles. Each of the roundabouts on Route N6 conforms to this design.

1.2 Problem definition

The installation of the roundabouts on Route N6 to replace the at-grade intersections was actually in line with modern trends in intersection control as worldwide, roundabouts have become a popular feature now gradually replacing traditional intersections, including those controlled by signals. However, shortly after the Kumasi–Ejisu section had been opened to traffic; accidents began to occur particularly at the University Police Station Roundabout, involving mostly trucks. What was baffling and surprising about the accidents was that even though all the roundabouts appear to have been designed to the same geometric standards, there was a preponderance of truck accidents at only one of them (University Police Station Roundabout). The accidents raised public concern and outcry against the roundabouts with some questioning their relevance in modern highway engineering and others calling for their immediate removal. Even though at present the euphoria surrounding the device following the initial spate of accidents has died down, some in the country still feel that the device has no place in modern highway engineering. The differences in the safety performance of the roundabouts raise several questions including truck use of the device, suitability of roundabouts on a highway, etc, that need to be addressed.

1.3 Research objectives

The objectives of the research were to:

1. Establish the number and character of accidents that have occurred at the roundabouts to date.
2. Evaluate the design features of the roundabouts.
3. Establish drivers' knowledge of use of roundabouts.
4. Establish truck manouevering characteristics at the roundabouts.

1.4 Justification

The research is justified by the fact that;

1. Safety on the roadway is an important feature of road transport.
2. Roundabouts use is likely to be on the increase in the country in future in line with modern trends in intersection control, therefore, it is necessary to address any peculiar problems associated with the installation and use of the device so as to ensure overall roadway safety.
3. There is the need to establish the proper use of modern roundabouts by trucks in the country considering our peculiar situation of using large trucks to haul almost all kinds of goods on the road.

1.5 Scope of work

The work involved in the study covered the following:

1. Literature review.

2. Collection of accident records and analysis of data on the four roundabouts.

3. Review of the as–built drawings of the roundabouts and the geometric characteristics of the roundabouts.

4. Conduction of roadside interview of truck drivers plying the road section.

5. Field observation of truck manoeuvres at the roundabouts using video technology.

2 LITERATURE REVIEW

2.1 History of roundabouts

The first concept of a roundabout or gyratory operation of vehicles, where all the traffic would be required to circulate in one direction, was invented by Eugene Henard in 1903 (see Figure 2.1).

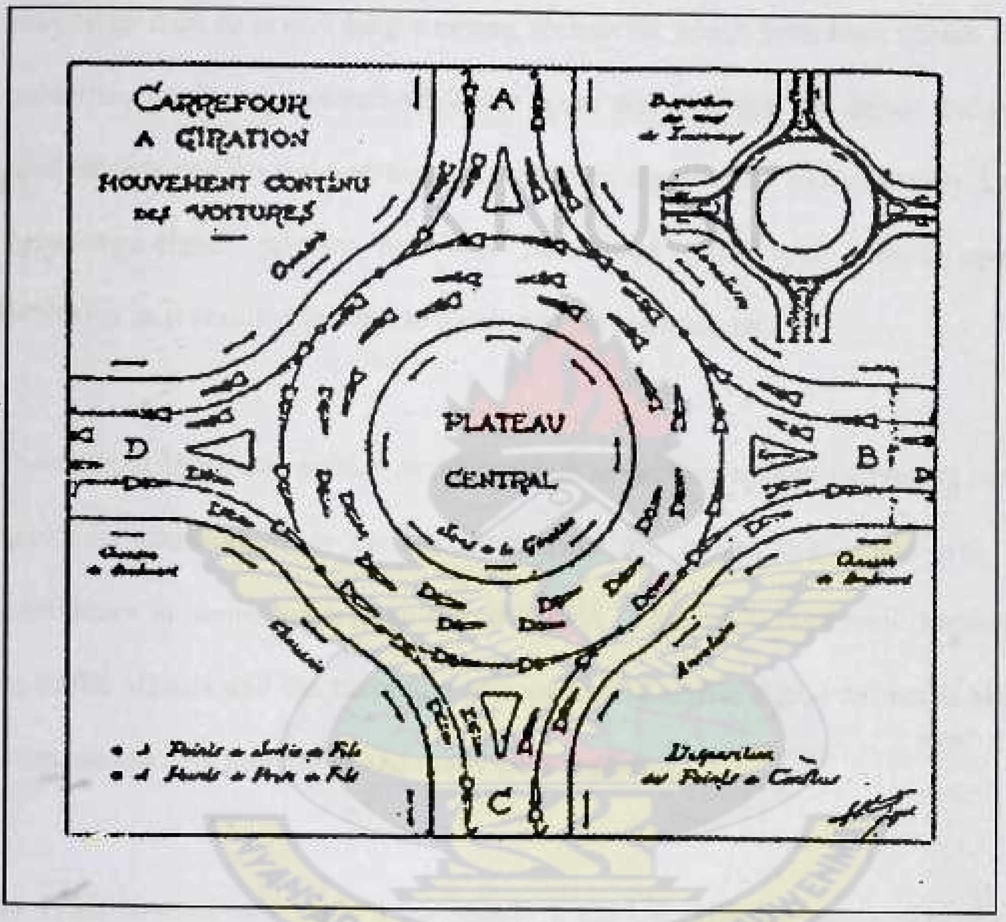


Figure 2.1. Hanard's suggested gyratory cross road (Brown, 1995)

The earliest practical use of a gyratory system was the Columbus Circle installed by William Phelps Eno in New York in 1905 (Taekratok, 1998). In France, the first roundabout was built in 1907 in Paris at the Place De l'Etoile. In the UK, roundabouts were introduced in London at Aldwych, Parliament Square, Hyde Park Corner, Marble Arch, and Trafalgar Square between 1925 and 1926 (Taekratok, 1998). In the United States, the first design guideline for a roundabout was published in 1942 by the American Association of State Highway Officials (AASHO) (Todd, 1988). A roundabout was defined as an intersection where all traffic merges into and emerges from a one–way road around a central island.

In the early roundabout design and operation, the concept was to design the device with large radii to give a long weaving section on which both high speeds and high capacities could be maintained. There were no set rules for driver behaviour at roundabouts and no right-of-way was given to a particular traffic stream. Later, the "give–way–right" priority rule was introduced. This rule created operational problems as it resulted in vehicle locking at the roundabout.

From about 1950, due mainly to the problem of locking and an increasing number of accidents resulting from drivers disobeying the traffic rule, there was loss of confidence in roundabouts as an effective form of intersection control. Improvements in traffic signals and the invention of coordinated traffic signal networks also made roundabouts less preferable and many were replaced.

In 1996, roundabouts made a comeback in the UK with the new assigned off–side priority rule (an entering vehicle gives way to circulating vehicles) and the yield–at–entry operation. With this new priority rule, entry was now controlled by the ability of entering drivers to detect gaps in the circulating flow. An entering vehicle simply merged into any suitable gap in the circulating flow and diverged as it reached the desired exit. These prevented vehicles from entering when no gap in the circulating stream was available, avoiding the locking problem. Today's roundabouts termed

" modern roundabouts" differ substantially from traffic circles as they have smaller radii, operate with yield-at-entry rule and cause substantial path deflection to force motorists to slow down as they negotiate the device.

The success of the modern roundabout provoked renewed interest in the use of roundabouts. In France, modern roundabouts were reintroduced in 1972 and yield-at-entry imposed in 1983. Since then, France has built about 20,000 modern roundabouts at the rate of about 1,000 per year and other countries have followed suit (Ken Sides, 2007).

2.2 Modern roundabouts

The term "modern roundabout" is used to differentiate today's roundabouts from the nonconforming circles or rotaries that were in use for many years. AASHTO (2004) defined modern roundabouts by three basic operational and design principles.

1. Yield–at–entry: Also known as off-side or the yield–to–left, yield–at–entry requires that vehicles on the circulatory roadway of the roundabout have the right–of–way and all entering vehicles on the approaches have to wait for a gap in the circulating flow. To maintain free flow and high capacity, yield signs are used as the entry control. As opposed to nonconforming traffic circles, modern roundabouts are not designed for weaving manoeuvres, thus permitting smaller diameters. Even for multilane roundabouts, weaving manoeuvres are not considered a design or capacity criterion.
2. Deflection of entering traffic: Entrance roadways that intersect the roundabout along a tangent to the circulatory roadway are not

permitted. Instead, entering traffic is deflected to the right by the central island of the roundabout and by channelization at the entrance into an appropriate curve path along the circulatory roadway. Thus, no traffic is permitted to follow a straight path through the roundabout.

3. Flare: The entry to a roundabout often flares out from one or two lanes to two or three lanes at the yield line to provide increased capacity.

Modern roundabouts range in size from mini – roundabouts with inscribed circle diameters as small as 15m, to compact roundabouts with inscribed diameters between 30 and 35m, to large roundabouts, with multilane circulatory roadways and more than four entries up to 150m in diameter. The greater speeds permitted by larger roundabouts, with inscribed circle diameters greater than 75m, may reduce their safety benefits to some degree (AASHTO, 2004). Figure 2.2 shows the basic geometric elements of a modern roundabout.

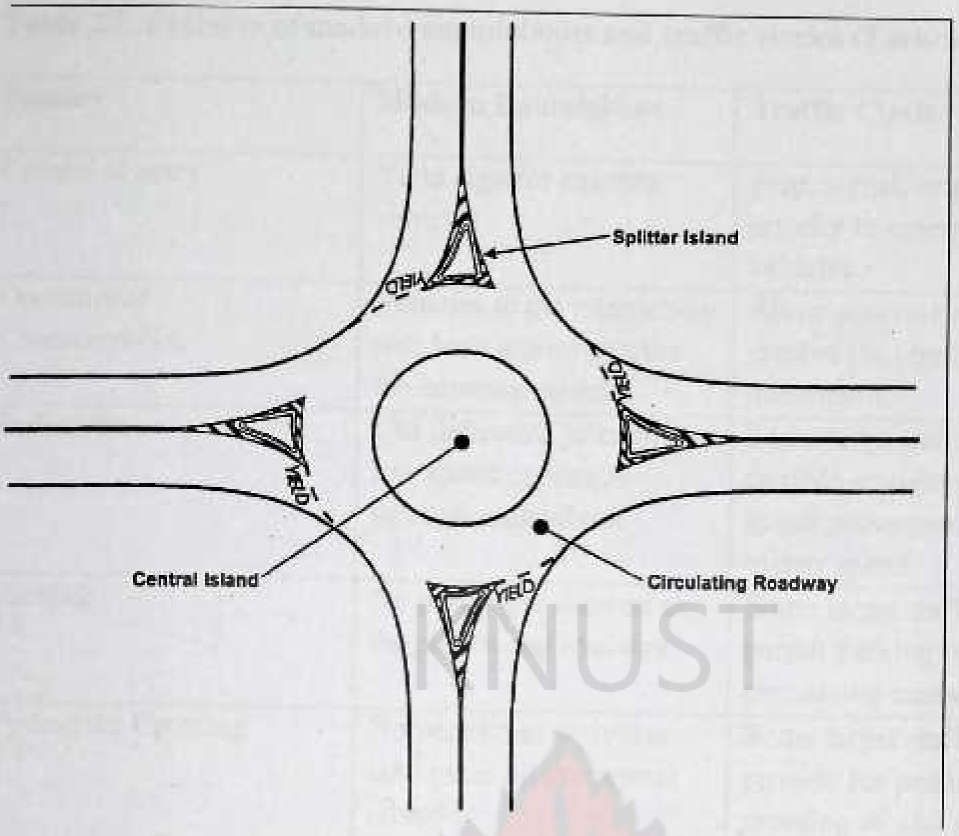


Figure 2.2. Basic geometric elements of modern roundabouts (Taekratok, 1998)

The common features that identify modern roundabouts and distinguish them from traffic circles are presented in Table 2.1.

Table 2.1. Features of modern roundabouts and traffic circles (Taekratok, 1998)

Feature	Modern Roundabout	Traffic Circle
Control at entry	Yield sign for entering vehicles	Stop, signal, or give priority to entering vehicles.
Operational Characteristics	Vehicles in the roundabout will have a priority over the entering vehicle	Allow weaving areas to resolve the conflicted movement.
Deflection	Use deflection to control low speed operation through roundabout	Some large traffic circles provide straight path for major movement with higher speed.
Parking	No parking is allowed on the circulating roadway	Some larger traffic circles permit parking within the circulating roadway
Pedestrian Crossing	No pedestrian activities take place on the central island	Some larger traffic circles provide for pedestrian crossing to, and activities on, the central island.
Turning Movement	All vehicles circulate around the central island	Mini-traffic circles, left – turning vehicles are expected to pass to the left of the central island.
Splitter Island	Required	Optional.

2.3 Types of roundabouts

Ourston and Doctors (1995) put roundabouts into six classes as follows:

1. Normal roundabout

   A normal roundabout is a roundabout with one way circulating roadway around a curbed central island of 4m or more in diameter. Figure 2.3 illustrates the features of a normal roundabout.

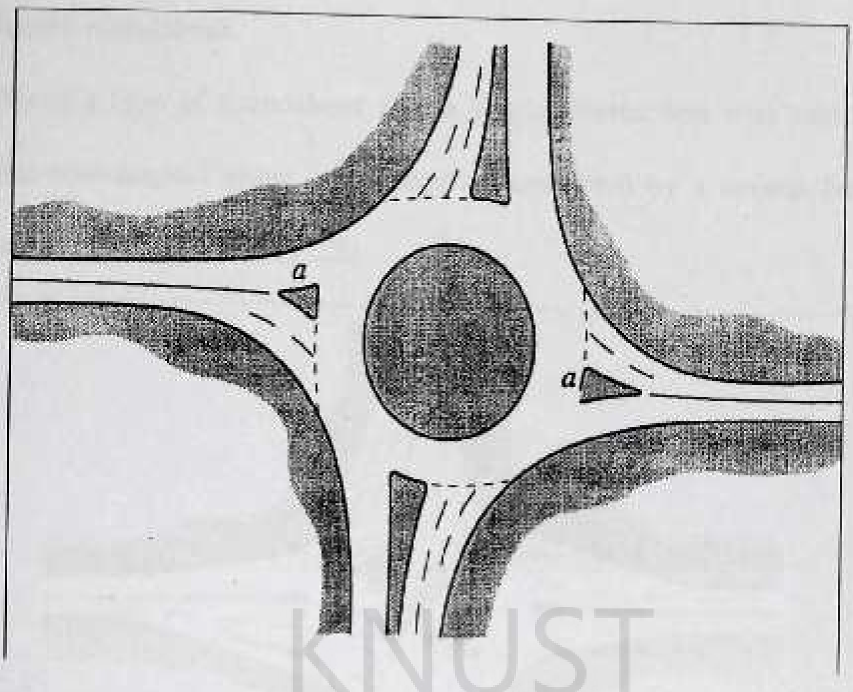


Figure 2.3. A normal roundabout (Taekratok, 1998)

2. Mini or small roundabout

   A small roundabout is a roundabout with a one-way circulating roadway around a slightly raised circular island less than 4m in diameter. A small roundabout is shown in Figure 2.4

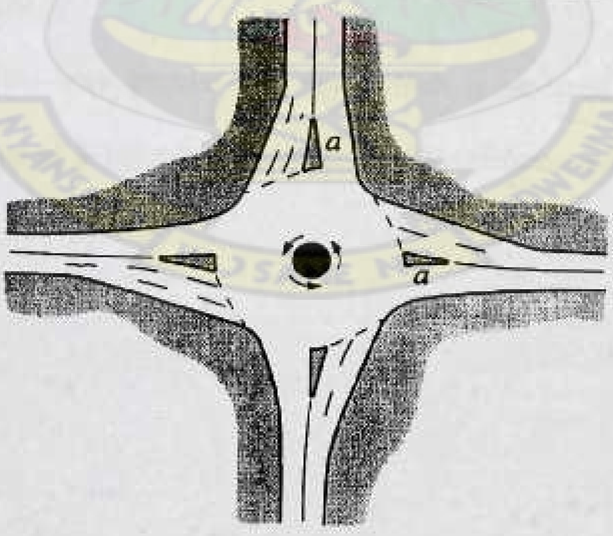


Figure 2.4. A mini or small roundabout (Taekratok, 1998)

3. Double roundabout

This is a type of roundabout with a single intersection with two normal or mini roundabouts either contiguous or connected by a central link road or curbed island (see Figure 2.5).

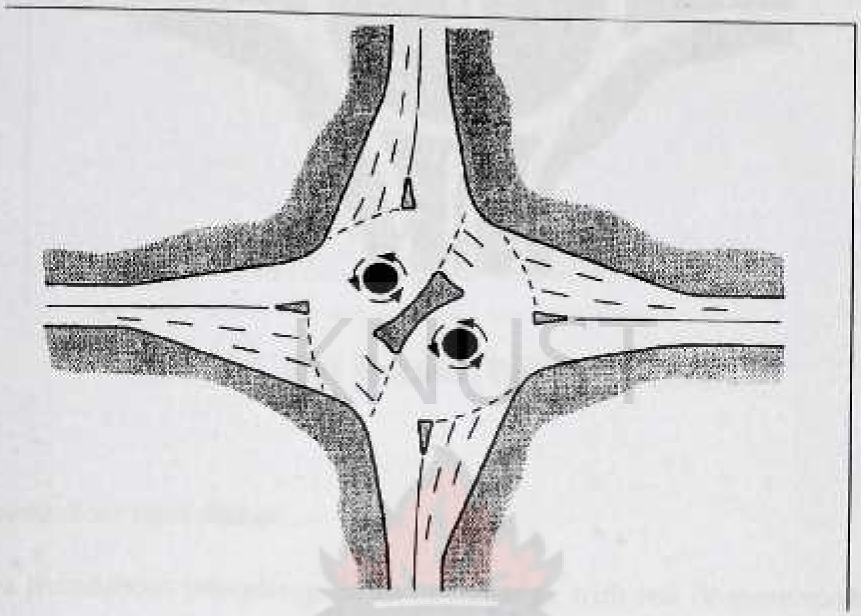


Figure 2.5. Double roundabout (Taekratok, 1998)

4. Ring junction

This is a two–way circular ring road which is assessed by external spoke roads by way of 3–leg mini roundabouts or T–intersections (see Figure 2.6).

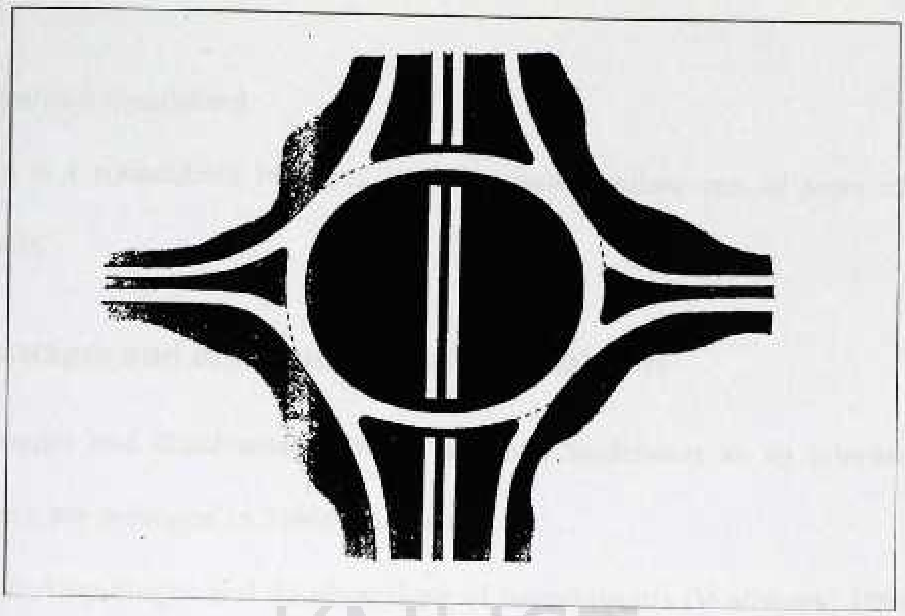


Figure 2.6. Ring junction (Taekratok, 1998)

5. Roundabout interchange

The roundabout interchange is an interchange with one or more roundabouts. The most common types are a freeway passing over or under one large roundabout which is joined by ramps and the cross street, and a roundabout at the ramps intersection with the cross street (see Figure 2.7).

Figure 2.7. Roundabout interchange (Taekratok, 1998)

6. Signalised roundabout

This is a roundabout in which traffic signals regulate one or more of the entries.

2.4 Advantages and disadvantages of roundabouts

The advantages and disadvantages of the use of roundabouts as an intersection control device are presented in Table 2.2 below.

Table 2.2. Advantages and disadvantages of roundabouts (Wallwork, 1995)

Category	Advantages	Disadvantages
Safety	-There are a reduced number of conflict points compared to an uncontrolled intersection -Lower operational speeds yield less severe and fewer accidents. -Slower speeds because of intersection geometry reduce accidents.	-Since roundabouts are unfamiliar to the average driver, there is likely to be an initial period where accidents increase. -Signalised intersections can pre-empt control for emergency vehicles.
Capacity	-Traffic yield rather than stops, often resulting in the acceptance of smaller gaps. -For isolated intersection, roundabouts should give higher capacity/lane than signalised intersections due to the omission of lost time (red and yellow) at signalised intersections.	-Where the coordinated signal network can be used, a signalised intersection will increase the overall capacity of the network. -Signal may be preferred at intersections that periodically operate at higher than designed capacities.
Delay	-The overall delay will probably be less than for equivalent volume signalised intersections(this does not equate to higher level of service) -During the off-peak, signalised intersections with no retiming produce unnecessary delays to stopped traffic when gaps on the other flow are available.	-Drivers may not like the geometric delays which for them to divert their cars from straight path. -When queuing develops, entering drivers tend to force into the circulating streams with shorter gaps. This may increase the delays on other legs and the number of accidents.
Cost	-In general, less right – of – way is required. -Maintenance costs of signalised intersections include electricity, maintenance of loops, signal heads, controller, and timing plans (roundabout maintenance includes only landscape maintenance, illumination, and occasional sign replacement). -Accident costs are low due to the low number of accidents and severity.	-Construction cost may be higher. -In some locations, roundabouts may require more illumination, increasing costs.

Pedestrians and Bicyclists	-A splitter island provides a refuge for pedestrians that will increase safety. -At low speed and low traffic volume, roundabouts should improve safety for bicyclists	-A splitter island may cause difficulty to people using wheel chairs -Tight dimension of roundabouts create an uncomfortable feeling to bicyclists. -Longer path increases travel distances for pedestrians and bicyclists. -Roundabout may increase delay for pedestrians seeking acceptable gaps to cross.

2.5 Geometric design of roundabouts

According to the capacity study of roundabouts in the UK, geometric elements of roundabouts play an important part in the efficiency of roundabout operational performance. Good design will improve not only capacity but also safety, which is a major concern for road design. The basic elements for design consideration of roundabouts are:

- Design vehicles
- Design speed
- Sight distance
- Deflection
- Central island
- Circulating width
- Inscribed circle diameter
- Entry and exit design
- Splitter island
- Superelevation and drainage
- Pavement markings
- Signing

- Lighting
- Landscaping

2.5.1 Alignment and grades at roundabout locations.

The alignment and grade of the intersecting roads at the location of a roundabout should permit users to recognize the roundabout and the other vehicles using it, and readily perform the manoeuvres needed to pass through the roundabout with minimum interference. To these ends, the alignment should be as straight and the gradient as flat as practical (AASHTO, 2004).

The recommended slope in Australia and some states in the United States are presented in Table 2.3.

Table 2.3. Recommended slopes at roundabout locations (Taekratok, 1998)

Country/State	Recommended Slope(m/m)
Florida	0.02 and min. 0.015 outward
California	0.02 and max 0.025 outward
Maryland	0.025 – 0.03 and min. 0.02 outward
Australia	0.025 – 0.03 and min. 0.02 outward

Generally, the cross slope at roundabouts can vary around the circulating lanes but it should remain within the range of ±0.02. Large trucks should be accommodated at crown. Locating roundabouts on grades greater than 2% should be avoided (Taekratok, 1998). However, according to French guidelines, installing a roundabout on a roadway with a grade lower than 3% is generally not a problem but, when the grade is greater than 6%, the installation becomes unsuitable. Also, areas of reverse superelevation on the circulating roadway, or areas of normal superelevation on the entrance and exit ramps, should not have lateral slopes greater than 3%. On roundabouts located on a sloped plane, no slope should be added to the normal slope of the circulating roadway. Placing a roundabout at the crest of a vertical curve of one of the intersecting roadways should be avoided, but if this must be done, then the diameter should not be too small. If a roundabout is located on a slope, or at the low point of a vertical curve, a smaller roundabout design makes it possible to reduce the slope of the circulating roadway by about 1 to 2%.

2.5.2 Design vehicle

Design layouts should accommodate the largest design vehicles likely to use roundabouts. In Ghana, the characteristics of the design vehicles used for the design of intersections are shown in Table 2.4. The large vehicle is used when height is the overriding consideration whereas the trailer is used when length is the overriding consideration. The design layouts should also take care of buses, emergency vehicles, or special purpose vehicles. Truck aprons are permitted, but care must be taken to ensure adequate deflection for smaller vehicles. It is also important to ensure that any turning movement will not interfere with bicyclists (Taekratok, 1998).

Table 2.4. Dimensions of GHA design vehicles (GHA, 1991)

Design Vehicle	Length (m)	Width (m)	Height (m)
Large Vehicle	12.0	2.5	4.0
Trailer	15.0	2.5	3.4

2.5.3 Design speed

One of the keys to the demonstrated success of roundabouts is the improvement in safety. Roundabouts have very low accident and injury rates. This is because roundabouts are inherently designed for low speeds. The design speed of roundabouts should be around 40-50km/h (Taekratok, 1998).

2.5.4 Path deflection at roundabouts

According to Taekratok (1998), the single most significant feature of a roundabout design is adequate entry through and exit deflections. Adequate deflection will facilitate safe roundabout operation. Adjusting the geometry of the entry and exit lanes to achieve the proper deflection will ensure the necessary reduction in speed. The following factors should be taken into consideration during design:

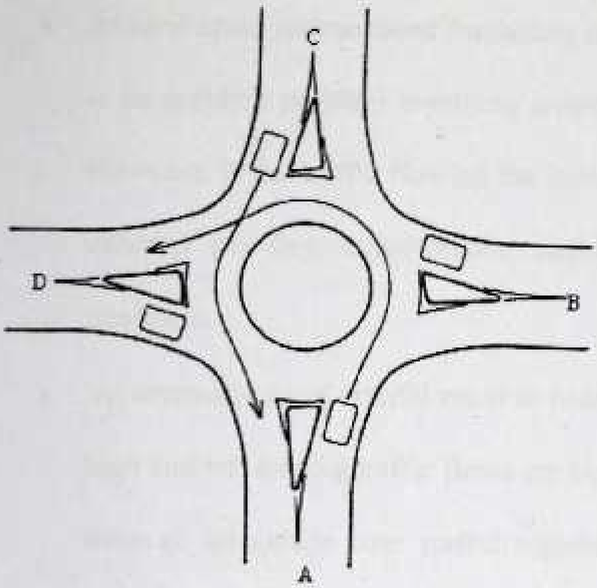
- Alignment of the entry road in conjunction with the shape, size and position of the approach splitter island;
- Provision of a suitable size and position of the central island; or
- Design of the roundabout with a staggered alignment between any entrance and exit.

Vehicle deflection is controlled by entry and exit radius, and the size of the central island or central island radius.

2.7 Roundabout locations

Austroad design guideline *(Austroad, 1993)* recommends the following locations as appropriate for the installation of roundabouts:

- At intersections where traffic volumes on the intersecting roads are such that STOP or YIELD signs or the T intersection rule result in unacceptable delays for the minor road traffic. In these situations, roundabouts would decrease delays to minor road traffic, but increase delays to the major road traffic.
- At intersections where traffic signals would result in greater delays than a roundabout. It should be noted that in many situations roundabouts provide a similar capacity to signals, but many operate with lower delays and better safety, particularly in off-peak periods.
- At intersections where there are high proportions of left-turning traffic. Unlike most other intersection treatments, roundabouts can operate efficiently with high volumes of left-turning vehicles. Indeed, these left-turning vehicles contribute to roundabout operation as is illustrated in Figure 2.8.



In this example the left-turner from A to D would stop the through movement from C to A, thus allowing traffic from D to enter the roundabout. Traffic from D would then stop the through movement from A thus allowing traffic from B to enter the roundabout. Left turners from A in this example would initiate traffic flow on adjacent entries B and D which would otherwise experience longer delay.

Figure 2.8. Movements at roundabouts (Austroad, 1993)

- At intersections with more than four legs. If one or more legs cannot be closed or relocated, or some turns prohibited, roundabouts can provide a convenient and effective treatment. With STOP or YIELD signs, it is often not practical to define priorities adequately, and signals may be less efficient due to the large number of phases required (resulting in a high proportion of lost time).
- At cross intersections of local and/or collector roads where a disproportionately high number of accidents occur which involve either crossing traffic or turning movements. In these situations, STOP or YIELD signs may make little or no improvement to safety, and traffic signals may not be appropriate because of the low traffic volumes. Roundabouts, however, have been shown to reduce the casualty accident rates at local and/or collector road intersections.
- On local roads, and to a lesser extent on arterial roads, roundabouts can improve safety and neighbourhood traffic management.

- At rural cross intersections (including those in high-speed areas) where there is an accident problem involving crossing or left turn (vs. opposing) traffic. However, if the traffic flow on the lower volume road is less than about 200 vehicles per day, consideration could be given to using a staggered T treatment.
- At intersections of arterial roads in outer urban areas where traffic speeds are high and left turning traffic flows are high. A well-designed roundabout could have an advantage over traffic signals in reducing left turn opposed type accidents and overall delays.
- At T or cross intersections where the major traffic route turns through a right angle. This often occurs on highways in country towns. In these situations the major movements within the intersection are turning movements which are accommodated effectively and safely at roundabouts.
- Where major roads intersect at Y or T junctions, as these usually involve a high proportion of left turning traffic.
- At locations where traffic growth is expected to be high and where future traffic patterns are uncertain or changeable.
- At intersections of local roads where it is desirable not to give priority to either road.

2.8 Drivers' perception about roundabouts

Roundabouts can provide substantial safety and traffic flow benefits compared with traffic signals and stop signs and, as a result, are increasingly used in place of a traditional intersection. However, construction of roundabouts can be hampered by negative perceptions held by some drivers. Studies have established that public support increases soon after roundabouts are built and drivers become familiar with them. In studies conducted in six communities in the United States, Retting et al (2007) found out that the proportion of drivers in favour of roundabouts generally ranged from 22 to 44 % before construction, 48 to 67 % shortly after the roundabout is built, and 57 to 87 after roundabouts were in place for at least one year. They also established that drivers agree that roundabouts improve safety and traffic flow mostly after use of the device for about 1-5 years.

In a survey conducted by the Insurance Institute for Highway Safety, it was established that the number of people who favour roundabouts almost double after using the roundabout, compared to those who favour the device before they are built (WSDOT, 2008).

2.9 Accidents at roundabouts

In spite of the safety benefits associated with roundabouts, accidents do occur at the location of these devices sometimes at a rate which could initially be higher than average, but then the accidents may reduce considerably as drivers gain experience in the use of the roundabout.

Accidents at roundabouts can be categorized into twelve types (Cedesund, 1998) as follows;

1) Collision with traffic island

2) Run-off outwards

3) Run-off onto central island

4) Rollover

5) "Squeezing" during circulation

6) Collision in exit

7) Rear-end collision

8) Collision in approach

9) Collision in exit

10) Bicycle or moped accident

11) Pedestrian accident

12) Others

Figure 2.9 shows the various types of accidents at roundabouts.

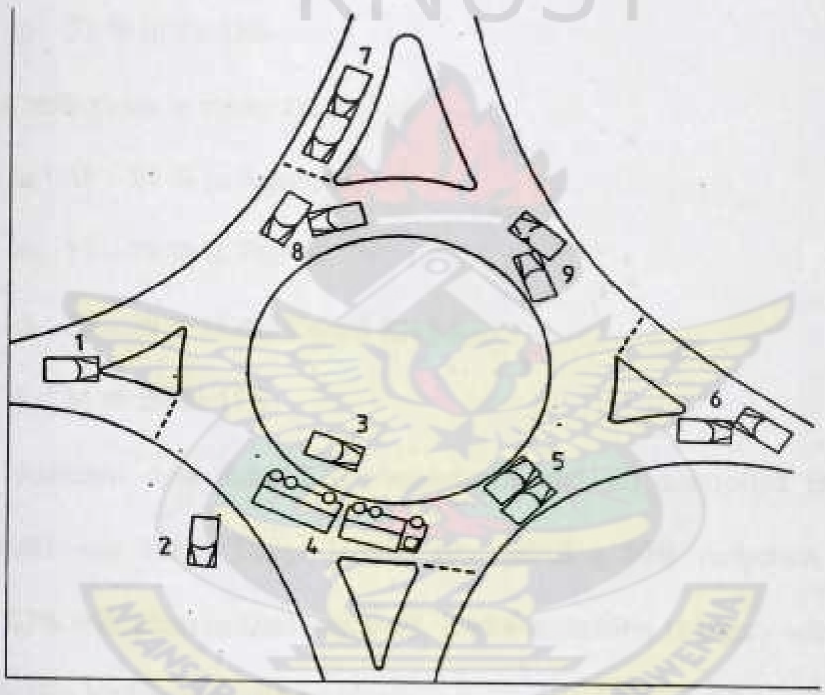


Figure 2.9. Different types of accidents in roundabouts (Cedersund,1988)

Hyden and Varhelyi (2000) found that replacing intersections with roundabouts carried a "very significant risk reduction" for bicyclists and pedestrians, but not for cars, whereas studies cited by Robinson et al (2000) claimed that crash reductions were most pronounced for motor vehicles, and smaller for pedestrians. Ourston and Hall (1997) reported slightly fewer crashes after converting intersections to roundabouts; however, the results were not found to be statistically significant (perhaps due to the size of the sample, not necessarily the magnitude of the effect). In a study by the Insurance Institute for Highway Safety, roundabouts were associated with large reductions in crashes and injuries (Persaud et al, 2000).

Studies cited by Robinson, et al (2000) found roundabouts to be associated with mean crash reductions of:

- 41 – 61 % in Australia,
- 36 % in Germany,
- 47 % in the Netherlands,
- 37 % in the U.S.,

and reductions in injury crashes of:

- 45 – 87 % in Australia,
- 57 – 78 % in France,
- 25 – 39 % in the United Kingdom,
- 51 % in the U.S.

Based on accident data from 230 roundabouts and 60 controlled intersections between 1981 and 1987, Tudge (1990) established a 50% reduction in overall accidents, 63% reduction in fatal accidents, a 45% reduction in injury accidents, and a 40% reduction in damage-only accidents.

2.10 Benefits of modern roundabouts

The benefits of roundabouts are listed below:

1. There are 75% fewer conflict points where intersection users' path cross
2. The most lethal crash types, the T-bone and head – on collisions are eliminated entirely by the central island.

3. Roundabouts are among the safest intersection designs available.
4. Roundabouts reduce serious injury and fatal accidents as vehicle speeds at such locations tend to be lower than at conventional intersections.
5. Roundabouts increase pedestrian safety and mobility
6. Roundabouts reduce traffic congestion
7. Roundabouts increase road capacity
8. Roundabouts reduce air and noise pollution
9. Roundabouts can be constructed to be an aesthetic and economic attribute to a community
10. Roundabouts take up the same or less space than a traditional signalised intersection
11. Roundabouts have an enormously positive cost/benefit ratio.

Crash severity is related to the kinetic energy of a crash which increases exponentially with the speeds of the vehicles involved. Roundabouts have two thirds fewer conflict points where paths of pedestrian cross those of vehicles than do cross intersections. That property and the much lower vehicle speeds make roundabouts safer for non-motorised users (Sides, 2007). Roundabouts when designed properly can provide substantial safety benefits compared with traditional intersections. It has been reported that crashes of all severities are reduced by about 40 percent and injury crashes by about 80 percent when signal or stop-control intersections are converted to roundabouts. Roundabouts also can significantly reduce vehicle delays, air pollution, and fuel consumption. In addition roundabouts make it possible to execute U-turns, improve access to intersections for motorists approaching from minor roads and represent a less expensive alternative for traffic control when social costs associated with accidents are taken into account.

3 METHODOLOGY

3.1 Field Work

3.1.1 Truck driver interview

A random sample of truck drivers were stopped with the help of the Police and interviewed on the spot at the University Police Station Roundabout and others at the Ejisu Roundabout. The interview also covered truck drivers stopped by the traffic signal at the Bomso signalised intersection, which is located on Route N6 and about one kilometre north of the University Police Station Roundabout.

The drivers were asked whether they favoured or opposed the installation of the roundabouts on Route N6. Truck drivers opposed to the roundabouts were further asked why they opposed the installation. In addition those opposed to the roundabouts were asked whether they had suggestions for making the roundabouts easier to use. The drivers were also asked for their opinion on the high accident rate at the University Police Station Roundabout compared to the other roundabouts. Questions were also asked the truck drivers on the significance of the truck apron which surrounds the central island of the roundabouts and the extent to which they use it (apron) and the difficulty when negotiating the roundabouts.

3.1.2 Truck manoeuvring at the roundabouts

Video technology was employed in the observation of truck use of the Police Station Roundabout. Vehicles were videotaped as they manoeuvred the roundabout in order to establish the swept path of trucks and truck-trailers relative to the truck apron. The truck manoeuvring characteristics recorded were then used to determine the proportion of trucks which use the truck apron when negotiating the roundabouts.

3.2 Secondary data collection

The secondary data collected were

- Accident records for the four intersections before and after conversion to roundabouts.
- As–built drawings for the four roundabouts

3.2.1 Accident records

Accident records for the four roundabouts for the period spanning June 2007 when the section was opened to traffic to the end of March 2008, the latest month for which accident data are available, were collected from the Building and Road Research Institute (BRRI) and from the files of the Police at the University Police Station. The accident records for the intersections before they were converted to roundabouts were also collected for the year 2004, 2005 and 2006. The accident data obtained covered:

- Accident numbers
- Collision or accident type
- Vehicle types involved
- Vehicle direction at the time of involvement in accident

3.2.2 As-built drawings of the roundabouts

The design features of the four roundabouts in terms of alignment details, grades, size of the central island and the truck apron were collected from the as–built drawings submitted to the Ghana Highway Authority the client for the rehabilitation of the Kumasi – Ejisu project. Figure 3.1 shows the location of the four roundabouts on the Kumasi-Ejisu section of Route N6.

Figure 3.1: Locations of the roundabouts on Route N6

4 RESULTS AND DISCUSSION

4.1 Accidents at the roundabouts

4.1.1 Accident numbers

A summary of the accidents that have occurred at the four roundabouts on the Ejisu-Kumasi section of Route N6 since June 2007, when the section was first opened to traffic to the end of March, 2008, the latest period for which accident data is available, is presented in Table 4.1.

Table 4.1. Accident summary for the four roundabouts.

Roundabout	Number of accidents	Percentage
University Police Station	12	75
Boadi	1	6
Oduom	3	19
Ejisu	0	0
TOTAL	**16**	**100**

As seen from the table, a total of 16 accidents have been recorded within the period under consideration. Of this number, 12 (75%) occurred at the University Police Station Roundabout alone. Within the same period, the Boadi Roundabout and the Oduom Roundabout recorded one and three accidents, respectively. So far, there has been no incident at the Ejisu Roundabout.

To be able to probe into the peculiar nature of the University Police Station roundabout which is experiencing a disproportionately high accident occurrence, it is worthwhile to look at the accident situation at the four intersections before conversion to roundabouts. Table 4.2 contains the accident summary for the locations for the three consecutive years, i.e., 2004, 2005 and 2006, preceding the conversion to roundabouts.

Table 4.2: Accidents at the intersections before conversion to roundabouts

Intersection location	Number of accidents		
	2004	2005	2006
University Police Station	3	2	1
Boadi	4	2	1
Oduom	2	0	3
Ejisu	1	0	0

It is seen from the general trend in the table that within the short-term, conversion of the intersections to roundabouts has not resulted in any dramatic change in the accident situation at the locations except at the University Police Station intersection where there has seen a dramatic deterioration in safety. This suggests that something is wrong at that location and casts doubt on its suitability for a roundabout.

4.1.2 Accident types

The distribution of the accident types at the four roundabouts for the year 2007 for which data was available is given in Table 4.3. below.

Table 4.3: Accident types at the roundabouts for 2007.

Roundabout Location	Accident type		
	Rollover	*Rear-end*	*Hit-pedestrian*
University Police Station	5	2	0
Boadi	0	0	1
Oduom	0	1	1
Ejisu	0	0	0
TOTAL	**5**	**3**	**2**

It is seen that of a total of 10 accidents that were recorded at the four roundabouts in 2007, five (50%) were rollover accidents; three (30%) were rear-end collisions; and two (20%) involved pedestrians who were hit while crossing the road.

4.1.3 Frequency of Accidents

To establish the trend of accident occurrence with time at the University Police Station Roundabout, it is worthwhile to look at the accidents occurrence per month. This was necessary to verify the trend when roundabouts are newly installed, accidents tend to be higher at the initial stages when devices are not familiar with the device than at later stages when familiarity with the devices goes up. The accident frequency from June 2007 to March 2008 is given in Table 4.4 below.

Table 4.4: Accident Frequency at University Police Station Roundabout

Month	Number of Accident
June	0
July	0
August	2
September	2
October	0
November	1
December	1
January	3
February	1
March	2
TOTAL	**12**

It is seen that no accidents were recorded during the first two months when the device in place. Even though accidents began to occur in subsequent months, on average, within the first six months of the installation of the device, the accident rate was 1 per month. Contrary to the normally held belief accidents began to occur at even a higher rate (an average of 2 per month) in the three months following the three months following the first six months of the installation. Clearly this shows that accident occurrence at the location of the roundabout cannot be limited to lack of familiarity of the device.

4.1.4 Vehicle types involved in accidents

Vehicular involvement in the 16 accidents that have occurred at the four roundabouts since their installation on Route N6 has been detailed in Table 4.5.

Table 4.5: Vehicular involvement in accidents at the roundabouts

Roundabout Location	**Vehicle type**			
	Car	*HGV*	*Mini-bus*	*Motorbike*
University Police Station	5	7	4	0
Boadi	1	0	0	0
Oduom	2	0	0	1
Ejisu	0	0	0	0
TOTAL	**8**	**7**	**4**	**1**

As is clear from the table, cars and HGVs are more disposed to accidents at the roundabouts than are other types of vehicles. What is interesting to note is the fact that even though HGVs and trucks in general constitute a little over 10% of the vehicular fleet on Route N6, here they constitute 35% of the vehicles that have been involved in the accidents at the roundabouts so far. In addition, data from the files of the Police indicate that all the rollover accidents indicated in Table 4.4 involved only HGVs with all of them taking place again at the Police Station Roundabout. As will be discussed later, it is believed that the propensity for HGVs to be involved in rollover accidents is related to a number of factors including the nature of the topography at the location of the roundabout and the manner in which the truck drivers use the roundabouts.

4.1.4.1 Travel direction of vehicles involved in accidents.

To bring to the fore the peculiar nature of the Police Station Roundabout, it would be worthwhile to take a look at the direction of travel of the vehicles at the time they were involved in accidents at the various roundabouts. Table 4.6 contains the summarised detail of the distribution of the travel directions of the vehicles at the time that they were involved in accidents at the roundabouts. The data represent the accidents for the year 2007 only as the directional information on the accidents for 2008 is not available.

Table 4.6: Distribution of travel direction of vehicle at the time of accident

Roundabout Location	**Vehicle's travel direction at time of accident**			
	North	*South*	*East*	*West*
University Police Station	6	2	1	1
Boadi	1	0	0	0
Oduom	0	1	2	0
Ejisu	0	0	0	0
TOTAL	**7**	**3**	**3**	**1**

The directional distribution in the above table is made with reference to the fact that Route N6 trends north-south at the section under consideration. It is again worth noting the skewness in the travel direction of the vehicles involved in accidents at the University Police Station Roundabout i.e. 60% of the vehicles were travelling north. For the other roundabouts, there is no specific directional trend.

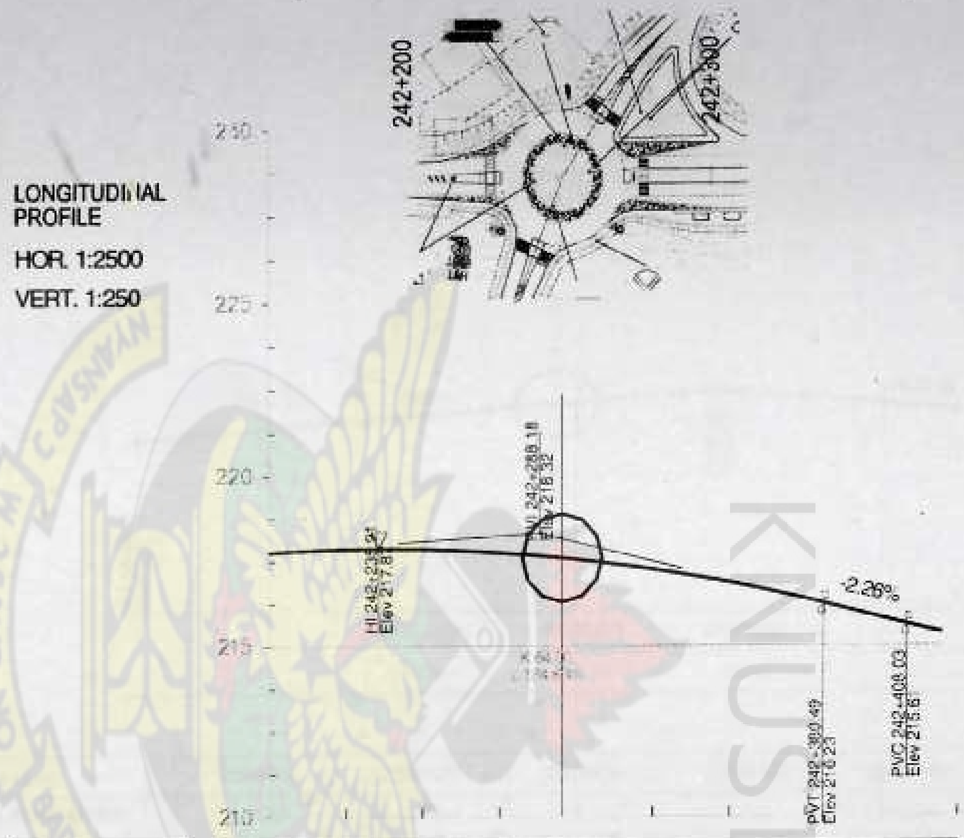
4.2 Plan and profile of the roundabouts

A review of the as-built drawings of the roundabouts indicated that the roundabouts were all built to the same standards with a central island of 10m diameter surrounded by a 3m-wide apron and a 6.5m circulatory roadway. In terms of topographical characteristics, the University Police Station Roundabout is located on a sag curve with the south approach having a long grade line with a slope of 4.67% and the north approach having a grade line with a slope of 3.65%. There is an intermediate grade line of 2.1% slope which is connected to the 4.67% grade by a vertical curve, but there is no such vertical curve connection between the 2.1% grade line and the 3.65% grade line to the north of the roundabout. The Boadi Roundabout was founded on a fill with a 3.5% slope. The Oduom Roundabout is located on a grade line of 1.0% slope whereas the Ejisu Roundabout is located on the crest of a vertical curve joining a 0.63% grade line to a 2.1% grade line. Table 4.7 gives a summary of the details of the characteristics of the topography at the various roundabout locations.

Table 4.7: Characteristics of the topography at the locations of the roundabouts

Roundabout	Characteristics of topography.
University Police Station	4.67% from Accra end, 3.65% from Kumasi, 2.1% middle. Roundabout is located in a sag curve.
Boadi	3.5% from Accra end, 3.5% from Kumasi end, Filling was done to achieve grades. Roundabout is located on a grade of 3.5%.
Oduom	1.0% from Accra end, 1.0% from Kumasi end Roundabout is located on grade of 1.0%.
Ejisu	On crest of the vertical curve connecting grades of 0.63% and 2.1%. Speed humps and rumble strips at the north approach.

The plan and profile of the roundabouts as mentioned above are shown in Fig. 4.1 to 4.4. and Appendix A1 shows the plan and profile of the rehabilitated Kumasi Ejisu section of Route N6.



STATION	242200	242250	242300	242350	242400
PR. ROAD LEVEL	[illegible]	217.86	217.54	216.86	215.79

Figure 4.1: Plan and profile of the Ejisu Roundabout

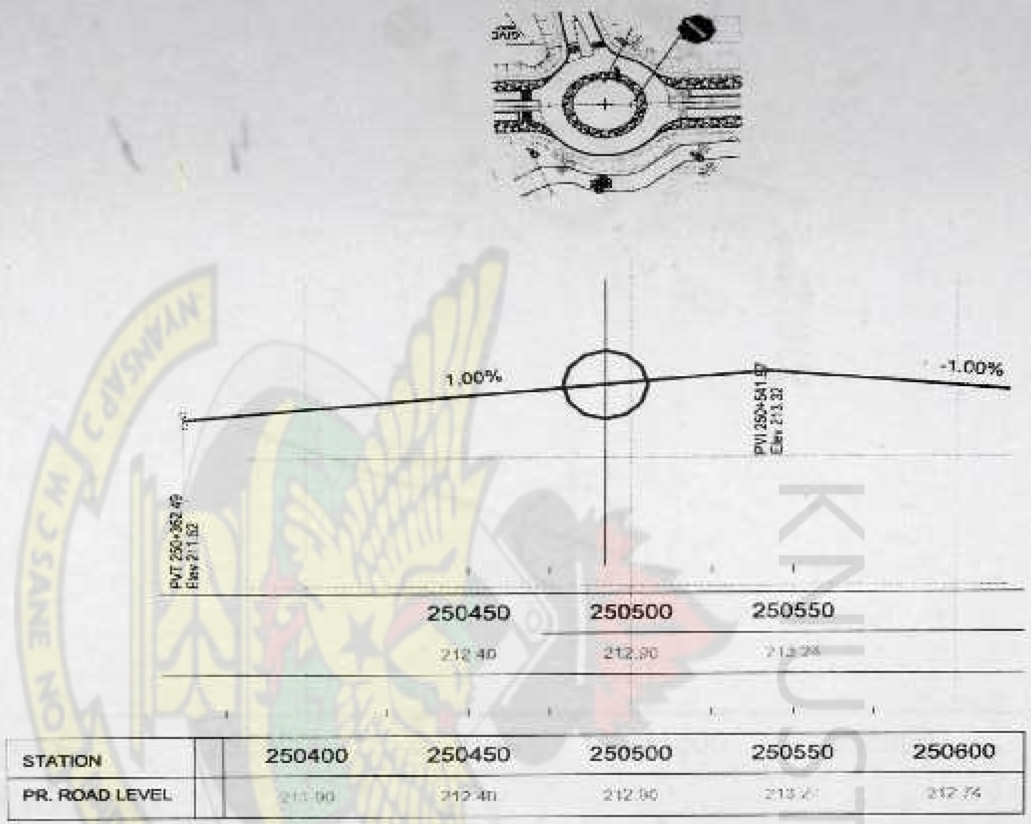
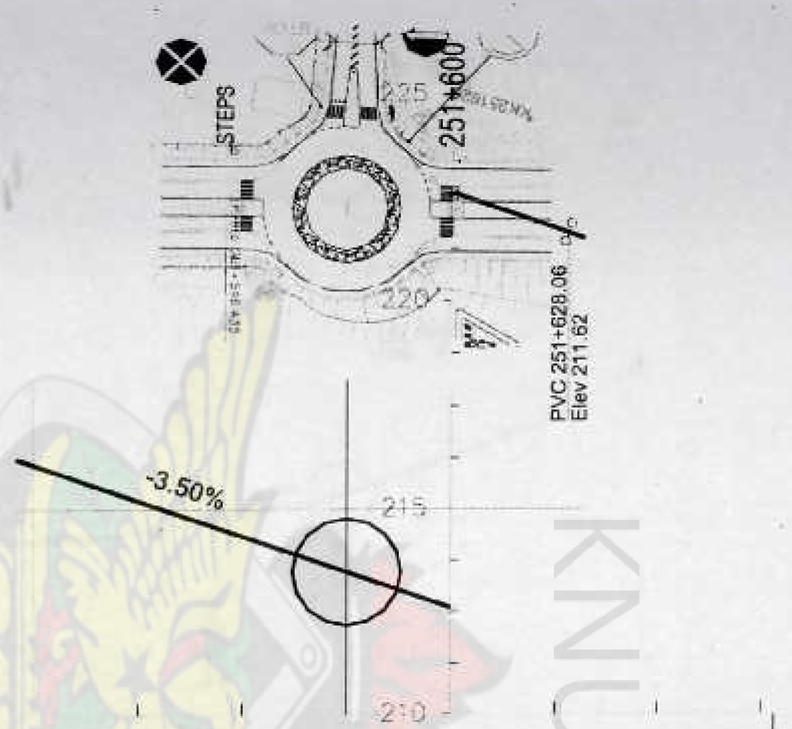


Figure 4.2 Plan and profile of the Oduom Roundabout



STATION	251500	251550	251600	251650
PR. ROAD LEVEL	216.11	214.36	212.61	210.89

Figure 4.3: Plan and profile of the Boadi Roundabout

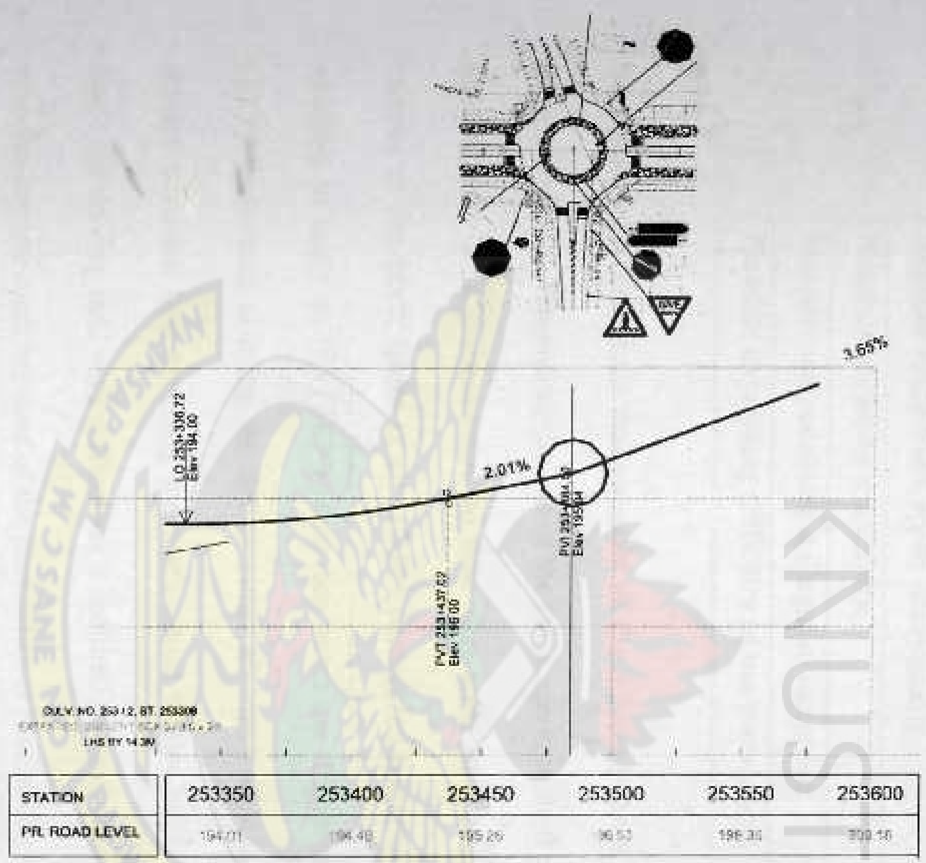


Figure 4.4: Plan and profile of the University Police Station Roundabout

4.3 Truck driver use of roundabouts

The results of the 240 truck drivers interviewed regarding the roundabouts and the truck apron are summarised in Table 4.8.

Table 4.8: Summary of driver interview on roundabouts

Number in favour of roundabouts	1
Number opposed to roundabouts	239
Number using truck apron always	30
Number using truck apron occasionally	25
Number not using truck apron	185
Number who consider it illegal to use apron	240
Number expressing difficulty of use roundabout	240

It is clear from the results that virtually all the drivers (99.6%) were not in favour of the roundabouts. Regarding the use of the truck apron in their manoeuvres around the roundabouts, it is disheartening to note that none of the drivers knew about the essence of the truck apron as all (100%) considered tracking it a traffic offence. In addition, as many as 185 (77.1%) said they never use the apron even though about 55 (22.9%) admitted to using the device either all times or occasionally. Also, all the drivers admitted that avoiding the truck apron whiles negotiating the roundabouts made the driving task very difficult as it required extra caution, especially when their vehicles carried load, because of the possibility of load shift.

On the specific issue of the high accident numbers at the University Police Station Roundabout, 239 (99.6%) of the truck drivers thought that the high slopes of the approaches contribute to the accidents at that roundabout. The same number also thought that the circulatory roadway of the roundabout was too small to allow for safe operation of trucks. Fifteen (6.25%) of the truck drivers thought that there is not adequate road signs to guide truck drivers for safe operation at the roundabout.

4.4 Truck manoeuvres at the roundabouts

A total of 187 trucks were captured on video whilst manoeuvring the University Police Station Roundabout. Of this number, 150 (80.2%) did not use the truck apron on the central island though an insignificant number (6, i.e., 3.2%) began their manoeuvres using the apron (flared cobbled-island) that reduces the entry to the roundabout to a single lane. Figure 4.5 shows a truck-trailer captured manoeuvring the University Police Station Roundabout.

Figure 4.5: A truck-trailer manoeuvring a roundabout

Quite clearly the results of the manoeuvre studies corroborate well with the truck driver interview in which, as already mentioned, 77.1% of the drivers admitted to not using the truck apron at all.

4.5 Discussion

The use of the roundabouts as a traffic control device on Route N6 is consistent with modern trends of intersection control. In spite of the huge public outcry against the construction of the device, three of the roundabouts namely the Boadi, Oduom, and Ejisu Roundabouts have so far recorded very low accidents. There has been no accident at the Ejisu Roundabout since its installation. Except for the roundabout at the University Police Station, a comparison of the accident numbers at the intersections before and after conversion to roundabouts does not point to deterioration in safety at the locations. So far, however, it is only the roundabout adjacent to the University Police Station which has experienced deterioration in safety. After almost one year, the accident rate at the University Police Station Roundabout has not reduced. Therefore the accident occurrence at the location cannot be wholly attributed to lack of familiarity with the device by truck drivers' which generally tends to be the case for roundabouts when newly installed.

The disproportionately high accident rate at the University Police Station Roundabout coupled with over-representation of trucks compared to the other roundabouts seems to be the culmination of several factors. One such factor is the non use of the truck apron on the central island by truck drivers to facilitate truck manoeuvres at the roundabouts. The fact that most of the truck accidents at that roundabout were roll-over accidents tends to suggest the possibility of the creation of load imbalance on the vehicles as drivers manoeuvre hard to avoid the truck apron. It is possible that as trucks and truck-trailers contort to follow the deflected path around the central island, they experience load shift leading to load imbalance on the load table of the trucks.

Clearly, the contention of the drivers during the interview that the circulatory roadway at the roundabouts are inadequate for the safe operation of trucks is rooted in the fact that they do not make use of the truck aprons to facilitate their manoeuvres at the roundabouts. It is quite obvious that even the few who make use of the apron do so looking over their shoulders because they consider their use illegal. Certainly, if the truck drivers had been using the truck apron, it could possibly have resulted in fewer roll-over accidents as the potential for load shifting could be almost absent. Once the drivers maintain the mindset that the truck apron is to be avoided, it is going to take a very long time for them to begin using it and roll-over accidents are unlikely to stop occurring. However, the situation could accidentally improve with time if a few more daring drivers began to "violate" the truck apron if they got to know that "violating" the apron actually facilitated their manoeuvres. The responses from the truck drivers during the interview seem to suggest that the few drivers who said they either use the apron all times or occasionally actually do so not because of knowledge but because they have discovered that using the apron actually helps the driving task at the roundabouts. A more pragmatic way of helping the situation is to mount driver education on the use of the roundabouts. In fact, this kind of education should have preceded the opening of the section to traffic.

An important question about the roundabouts that must be addressed is the differences in their performance in spite of the fact that they were all designed to the same standards. Of course, naturally, the similarity in the design should not cause any significant differences in performance to emerge but the topographical characteristics at the locations of the roundabouts which are different for each of the roundabouts seem to be the key factor causing performance differences. Compare, for example, the excellent safety record of the Ejisu Roundabout where the terrain is relatively flat (0.63% and 21.% for the approach grades) to the poor performance of the University Police Station Roundabout where the approaches to the roundabout have high gradients (4.67 % and 3.65%). Because the University Police Station Roundabout unlike the other roundabouts is located on a sag curve, it is approached from both the north and south approaches by vehicles descending a steep slope (see Fig. 4.6). This makes the roundabout location a bit queer and significantly different in character from those of the rest as high approach speeds are likely to be occurring.

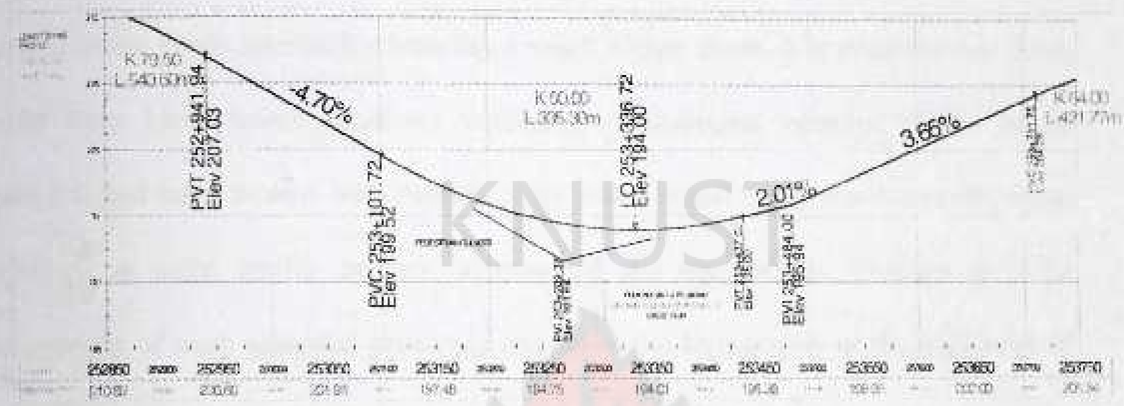


Figure 4.6: Details of the vertical profile of the University Police Station Roundabout

The contention of the truck drivers that the approach grades at the University Police Station Roundabout contribute to the high occurrence of accidents at that location is supported by the apparent uni-directional nature of most (6 out 10 or 60%) of the accidents that took place at that location in 2007. The gradient of 4.67% characterising the south approach to the roundabout is a bit too steep and probably causes vehicles to arrive at the roundabout from this approach with speeds that are relatively higher than the average speeds at the approaches to the other roundabouts.

Even though speed data were not collected at the roundabouts, high approach speeds cannot be ruled out due to the long and steep nature of the approaches. In fact the installation of rumble strips and a speed hump on the north approach of this roundabout to calm traffic arriving on the approach grade of 3.65% tends to support this stance as, so far, only 20% of the accidents recorded at the roundabout involved vehicles that were south-bound. It is not clear why similar safety treatments were not applied to the south approach which has a much higher slope. It is possible that there could have been fewer accidents involving north-bound vehicles if the south approach had been treated with rumble strips and a speed hump similar to the north approach to calm traffic as they approached the roundabout. Perhaps it is in anticipation of such potential problems related to the topography at the locations of roundabouts that some installation guidelines (e.g. French Guidelines) consider locations with grades above 3% as unfavourable for the installation of roundabouts.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the results of this study, the following conclusions may be drawn:

1. The fact that HGVs constitute 35% of the vehicles that have been involved in the accidents at the roundabouts on Route N6, even though they constitute only a little over 10% of the vehicular fleet, suggests that trucks and HGVs in general have a peculiar problem using the roundabouts.
2. An overwhelming majority of the truck drivers who use the roundabouts on the Ejisu-Kumasi section of Route N6 do not make use of the truck apron on the roundabouts to facilitate their movements simply because of sheer ignorance.
3. Perhaps if the truck drivers using Route N6 had been using the truck aprons on the roundabouts to facilitate their driving task, truck accidents at the roundabouts could have been fewer.
4. The differences in the safety performance of the roundabouts, in spite of the similarities in their (latter's) design, appear to be due to the differences in the characteristics of the topography at the locations of the roundabouts.
5. The preponderance of truck accidents at the University Police Station Roundabout compared to the other roundabouts on the section appears to be a combination of several factors including the location of the roundabout on a sag curve, the steepness of the approach grades and truck driver non use of the truck apron.

6. The high incidence of truck rollover accidents at one particular roundabout appears to suggest the possibility of vehicle imbalance created by load shift and probably high approach speeds as the vehicles negotiate the roundabout.
7. The opening of the rehabilitated section of Route N6 to traffic following the installation of the roundabouts should have been preceded by elaborate truck driver education on the proper use of the roundabouts.

5.2 Recommendations

Based on the above conclusions, it is recommended that

1. To reduce the high incidence of accidents at the University Police Station Roundabout, traffic calming measures similar to those applied on the north approach to the roundabout should be applied on the south approach.
2. Urgent and immediate driver education on the proper use of the roundabouts should be undertaken.
3. Further studies need be undertaken on standards for grades and topography appropriate for roundabouts in Ghana considering the truck loading characteristics in the country.

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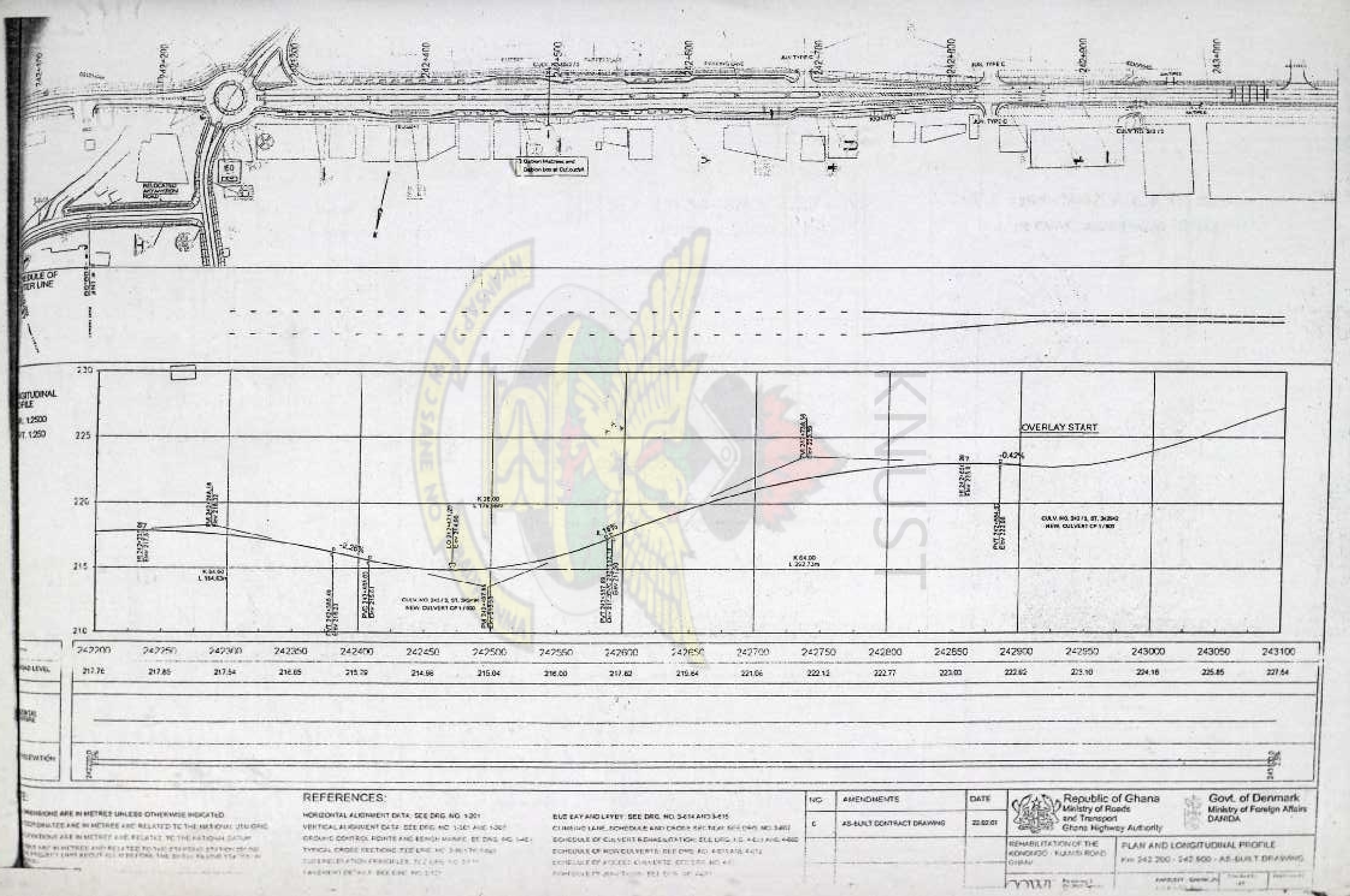
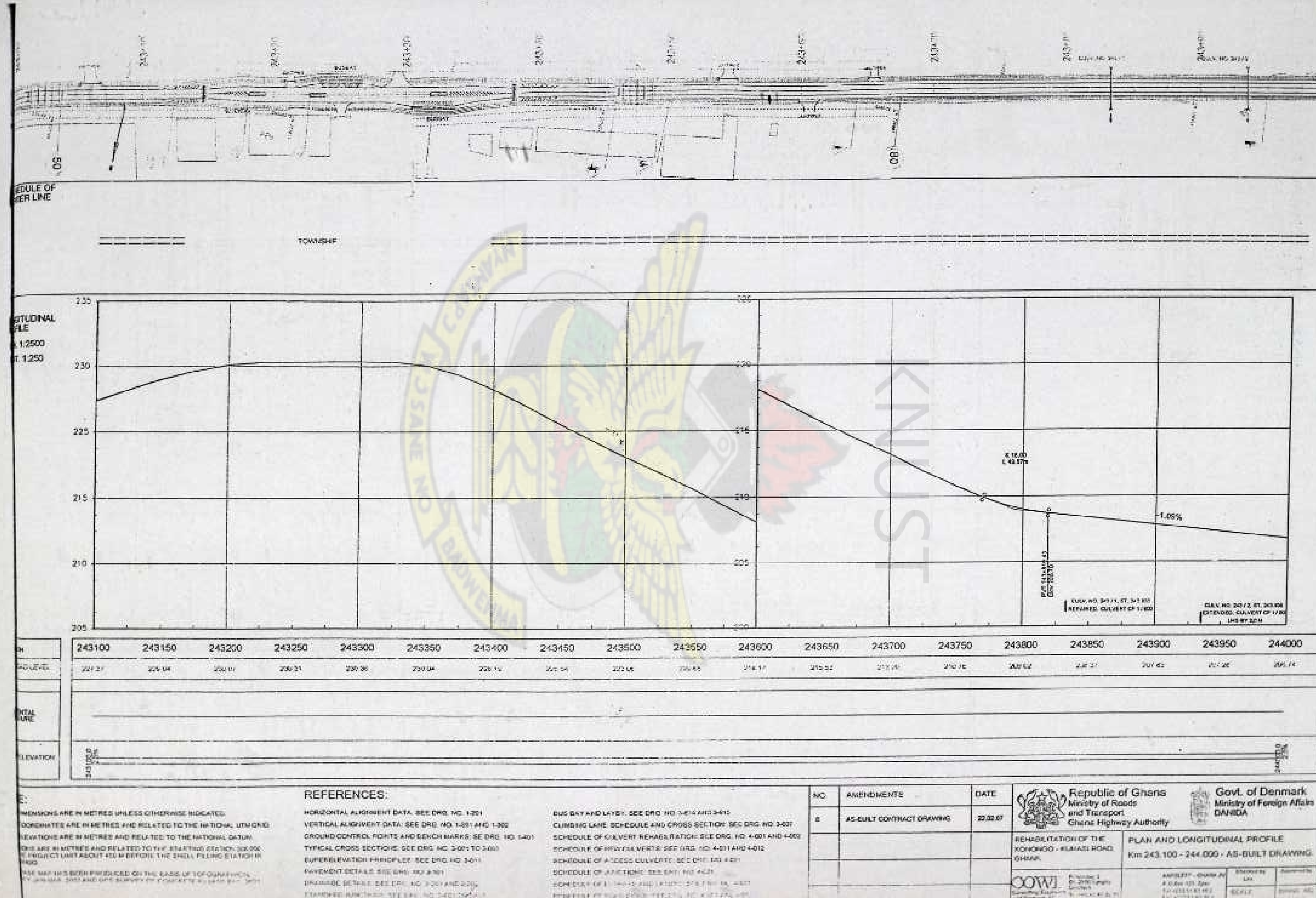
18. . Washington State Department of Transportation (2008). "Driving Roundabouts. Public Opinion of Roundabouts".
http://www.wsdot.wa.gov/Projects/roundabouts/opinion

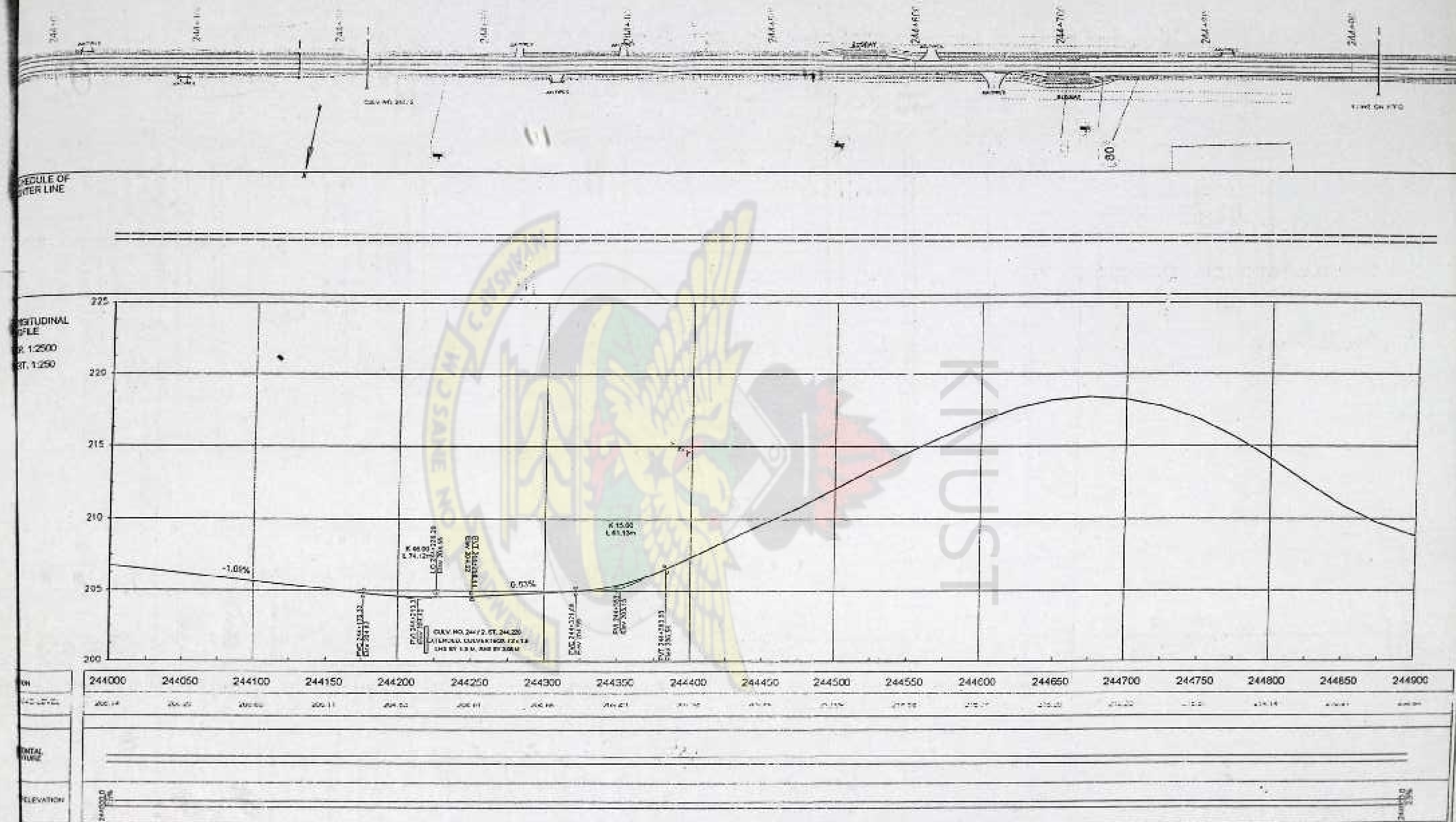
APPEDDIX A1: PLAN AND PROFILE OF KUMASI-EJISU SECTION OF ROUTE N6



OVERLAY START
-0.42%
-2.26%
K 64.00
L 202.72m
CULV. NO. 242/3, ST. 242+562
NEW CULVERT OF 1/900
242200 242250 242300 242350 242400 242450 242500 242550 242600 242650 242700 242750 242800 242850 242900 242950 243000 243050 243100
217.76 217.85 217.54 216.65 215.29 214.96 215.04 216.00 217.62 219.64 221.06 222.12 222.77 223.03 222.92 223.10 224.16 225.85 227.54
REFERENCES:
HORIZONTAL ALIGNMENT DATA: SEE DRG. NO. 1-201
NO.
AMENDMENTS
DATE
C
AS-BUILT CONTRACT DRAWING
22.02.01
Republic of Ghana
Ministry of Roads and Transport
Ghana Highway Authority
Govt. of Denmark
Ministry of Foreign Affairs
DANIDA
REHABILITATION OF THE KONONGO - KUMASI ROAD
PLAN AND LONGITUDINAL PROFILE
KM 242 200 - 242 900 - AS-BUILT DRAWING



SCHEDULE OF
TOWNSHIP
LONGITUDINAL PROFILE
1:2500
1:250
235
230
225
215
210
205
1.05%
243100
243150
243200
243250
243300
243350
243400
243450
243500
243550
243600
243650
243700
243750
243800
243850
243900
243950
244000
ELEVATION
REFERENCES:
HORIZONTAL ALIGNMENT DATA: SEE DRG. NO. 1-201
VERTICAL ALIGNMENT DATA: SEE DRG. NO. 1-301 AND 1-302
GROUND CONTROL POINTS AND BENCH MARKS: SEE DRG. NO. 1-401
TYPICAL CROSS SECTIONS: SEE DRG. NO. 2-001 TO 2-003
SUPERELEVATION PRINCIPLES: SEE DRG. NO. 3-011
BUS BAY AND LAYBY: SEE DRG. NO. 3-014 AND 3-015
CLIMBING LANE SCHEDULE AND CROSS SECTION: SEE DRG. NO. 3-037
DIMENSIONS ARE IN METRES UNLESS OTHERWISE INDICATED.
COORDINATES ARE IN METRES AND RELATED TO THE NATIONAL UTM GRID
ELEVATIONS ARE IN METRES AND RELATED TO THE NATIONAL DATUM
NO.
AMENDMENTS
DATE
AS-BUILT CONTRACT DRAWING
22.02.07
Republic of Ghana
Ministry of Roads and Transport
Ghana Highway Authority
Govt. of Denmark
Ministry of Foreign Affairs
DANIDA
REHABILITATION OF THE KONONGO - KUMASI ROAD, GHANA
PLAN AND LONGITUDINAL PROFILE
Km 243.100 - 244.000 - AS-BUILT DRAWING
COWI



NOTE:

DIMENSIONS ARE IN METRES UNLESS OTHERWISE INDICATED.
COORDINATES ARE IN METRES AND RELATED TO THE NATIONAL UTM GRID.
ELEVATIONS ARE IN METRES AND RELATED TO THE NATIONAL DATUM.

REFERENCES:

HORIZONTAL ALIGNMENT DATA: SEE DRG. NO. 1-201
VERTICAL ALIGNMENT DATA: SEE DRG. NO. 1-301 AND 1-302
GROUND CONTROL POINTS AND BENCH MARKS: SEE DRG. NO. 1-401
TYPICAL CROSS SECTIONS: SEE DRG. NO. 3-001 TO 3-003
SUPERELEVATION PRINCIPLES: SEE DRG. NO. 3-011
PAVEMENT DETAILS: SEE DRG. NO. 3-101
DRAINAGE DETAILS: SEE DRG. NO. 2-201 AND 2-202

BUS BAY AND LAYBY: SEE DRG. NO. 3-614 AND 3-615
CLIMBING LANE, SCHEDULE AND CROSS SECTION: SEE DRG. NO. 3-607
SCHEDULE OF CULVERT REHABILITATION: SEE DRG. NO. 4-001 AND 4-002
SCHEDULE OF NEW CULVERTS: SEE DRG. NO. 4-011 AND 4-012
SCHEDULE OF ACCESS CULVERTS: SEE DRG. NO. 4-021

NO	AMENDMENTS	DATE
6	AS-BUILT CONTRACT DRAWING	22.02.07

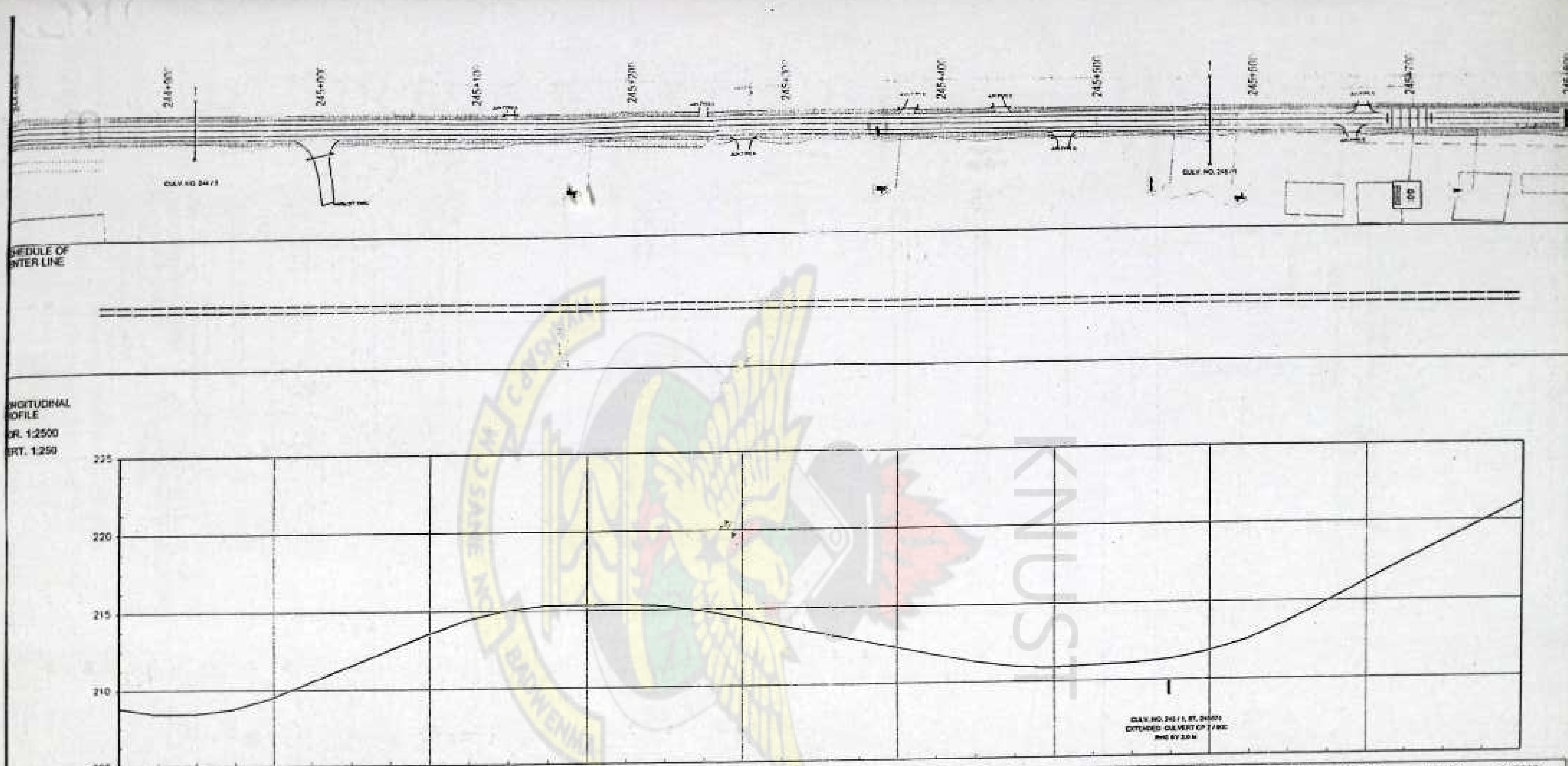
Republic of Ghana
Ministry of Roads and Transport
Ghana Highway Authority

Govt. of Denmark
Ministry of Foreign Affairs
DANIDA

REHABILITATION OF THE KONONGO - KUMASI ROAD GHANA

PLAN AND LONGITUDINAL PROFILE
Km 244,000 - 244,900 - AS-BUILT DRAWING

COWI



STATION	244900	244950	245000	245050	245100	245150	245200	245250	245300	245350	245400	245450	245500	245550	245600	245650	245700	245750	245800
ROAD LEVEL	208.84	208.44	209.53	211.57	213.50	215.04	215.54	215.22	214.35	213.27	212.25	211.35	210.90	211.12	211.87	213.71	216.26	218.75	221.23

HORIZONTAL CURVATURE

SUPERELEVATION

NOTE:

ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE INDICATED

ALL COORDINATES ARE IN METRES AND RELATED TO THE NATIONAL UTM GRID

ALL ELEVATIONS ARE IN METRES AND RELATED TO THE NATIONAL DATUM

STATIONS ARE IN METRES AND RELATED TO THE STARTING STATION [illegible]

THE [illegible]

REFERENCES:

HORIZONTAL ALIGNMENT DATA: SEE DRG. NO. 1-201

VERTICAL ALIGNMENT DATA: SEE DRG. NO. 1-301 AND 1-302

GROUND CONTROL POINTS AND BENCH MARKS: SEE DRG. NO. 1-401

TYPICAL CROSS SECTIONS: SEE DRG. NO. 3-001 TO 3-003

SUPERELEVATION PRINCIPLES: SEE DRG. NO. 3-011

PAVEMENT DETAILS: SEE DRG. NO. 3-101

DRAINAGE DETAILS: SEE DRG. NO. 3-201 AND 3-202

BUS BAY AND LAYBY: SEE DRG. NO. 3-614 AND 3-615

CLIMBING LANE, SCHEDULE AND CROSS SECTION: SEE DRG. NO. 3-407

SCHEDULE OF CULVERT REHABILITATION: SEE DRG. NO. 4-001 AND 4-002

SCHEDULE OF NEW CULVERTS: SEE DRG. NO. 4-011 AND 4-012

SCHEDULE OF ACCESS CULVERTS: SEE DRG. NO. 4-021

SCHEDULE OF JUNCTIONS: [illegible]

SCHEDULE OF [illegible]

NO.	AMENDMENTS	DATE
E	AS-BUILT CONTRACT DRAWING	22.03.07

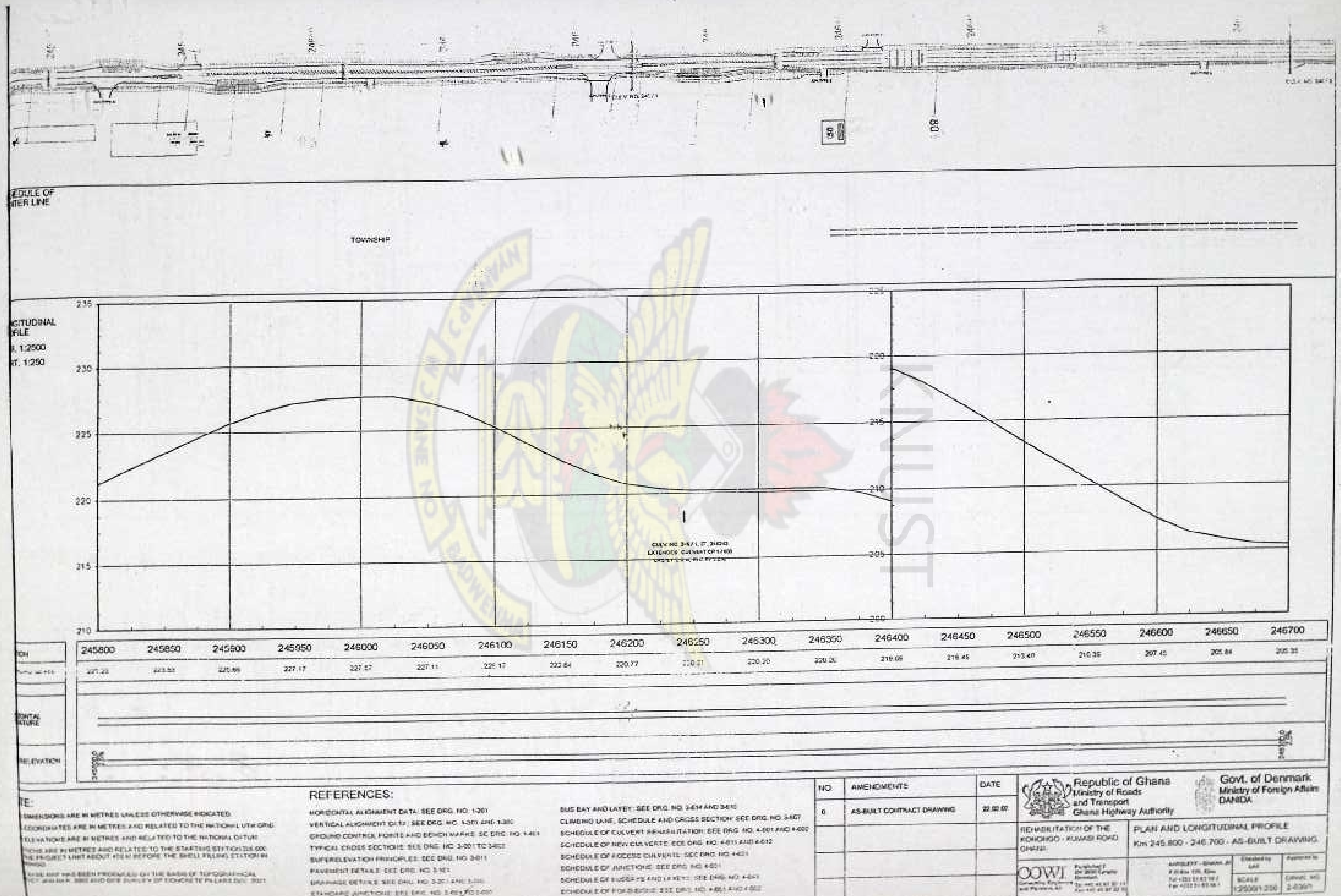
Republic of Ghana
Ministry of Roads and Transport
Ghana Highway Authority

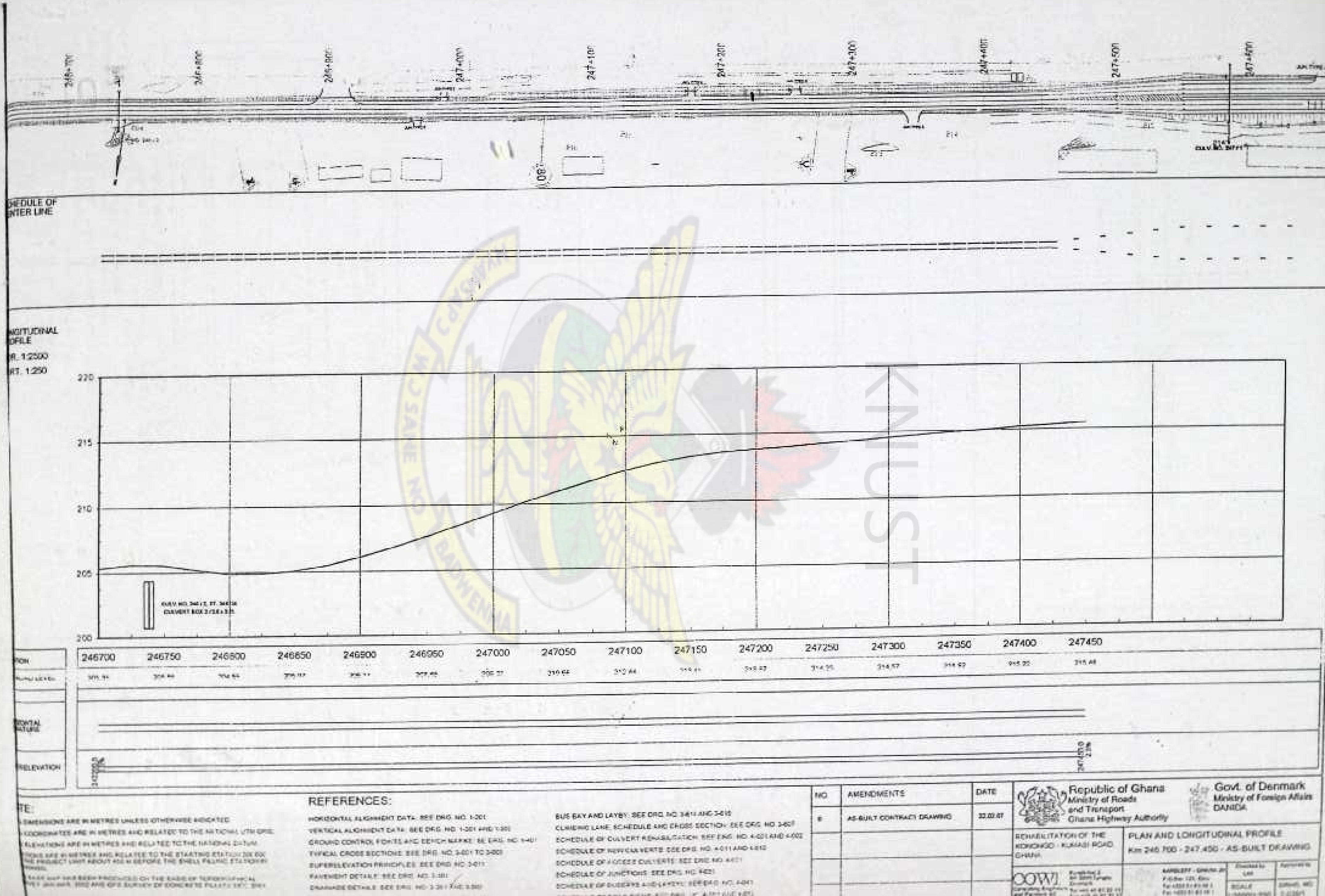
Govt. of Denmark
Ministry of Foreign Affairs
DANIDA

REHABILITATION OF THE KONONGO - KUMASI ROAD, GHANA

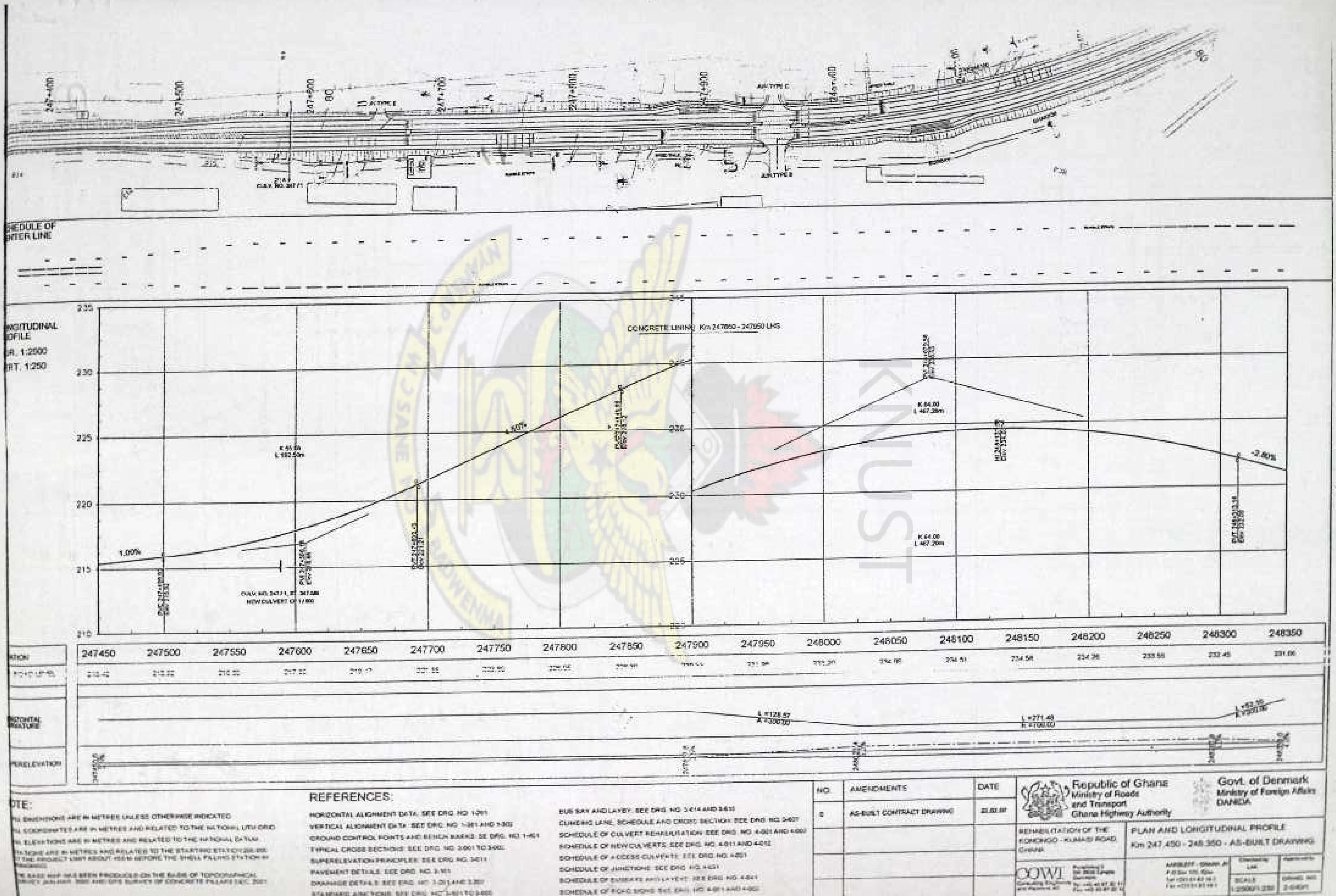
PLAN AND LONGITUDINAL PROFILE
Km 244.800 - 245.800 - AS-BUILT DRAWING

COWI

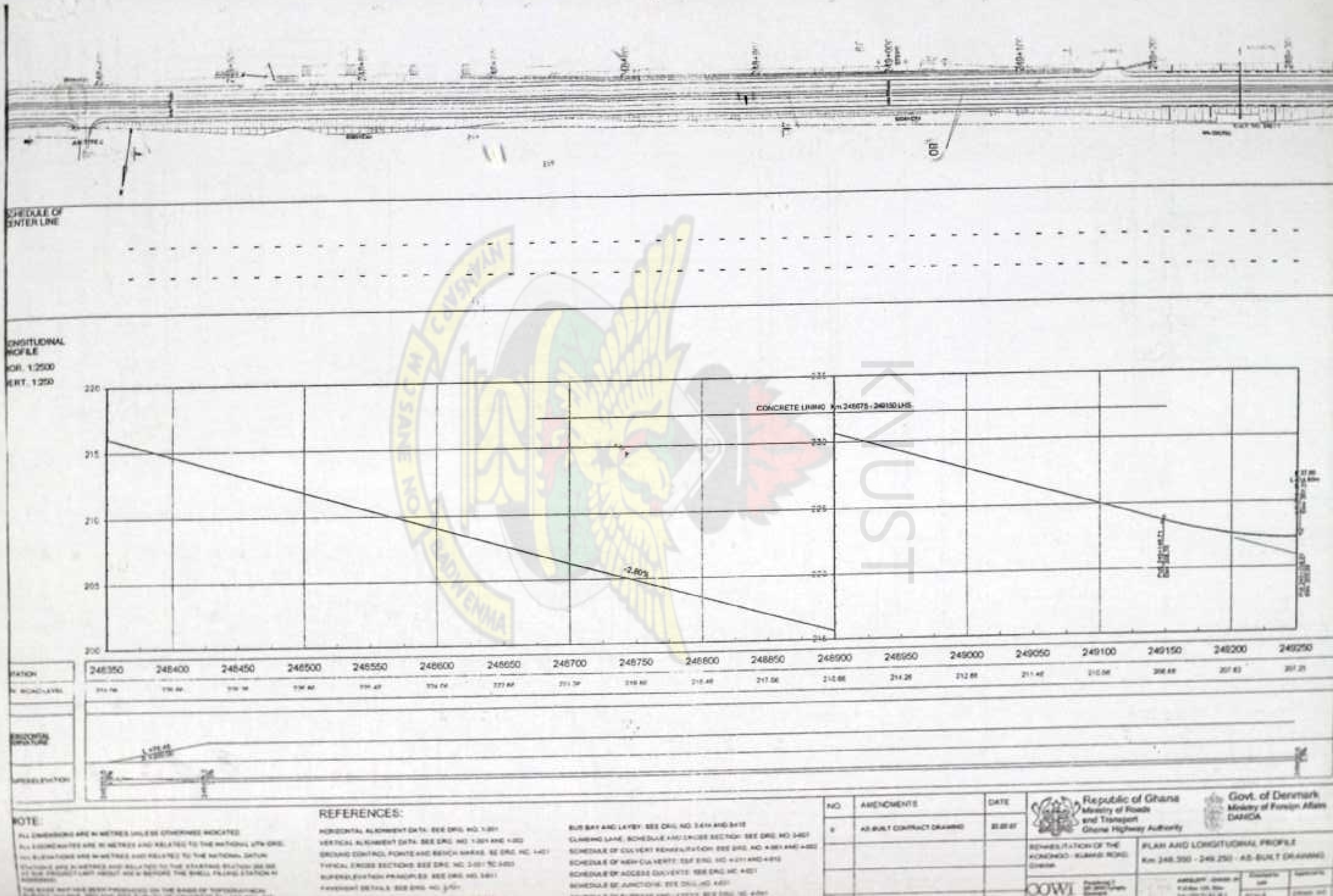

TOWNSHIP
245800
245850
245900
245950
246000
246050
246100
246150
246200
246250
246300
246350
246400
246450
246500
246550
246600
246650
246700
227.22
223.53
225.66
227.17
227.57
227.11
225.17
222.64
220.77
220.21
220.20
220.26
219.09
216.45
213.40
210.39
207.45
205.84
205.35
235
230
225
220
215
210
205
200
REFERENCES:
HORIZONTAL ALIGNMENT DATA: SEE DRG. NO. 1-201
VERTICAL ALIGNMENT DATA: SEE DRG. NO. 1-201 AND 1-301
GROUND CONTROL POINTS AND BENCH MARKS: SEE DRG. NO. 1-401
TYPICAL CROSS SECTIONS: SEE DRG. NO. 3-201 TO 3-402
SUPERELEVATION PRINCIPLES: SEE DRG. NO. 3-011
PAVEMENT DETAILS: SEE DRG. NO. 3-101
BUS BAY AND LAYBY: SEE DRG. NO. 3-614 AND 3-610
CLIMBING LANE, SCHEDULE AND CROSS SECTION: SEE DRG. NO. 3-607
SCHEDULE OF CULVERT REHABILITATION: SEE DRG. NO. 4-001 AND 4-002
SCHEDULE OF NEW CULVERTS: SEE DRG. NO. 4-611 AND 4-612
SCHEDULE OF ACCESS CULVERTS: SEE DRG. NO. 4-621
SCHEDULE OF JUNCTIONS: SEE DRG. NO. 4-601
NO.
AMENDMENTS
DATE
0
AS-BUILT CONTRACT DRAWING
Republic of Ghana
Ministry of Roads and Transport
Ghana Highway Authority
Govt. of Denmark
Ministry of Foreign Affairs
DANIDA
REHABILITATION OF THE KONONGO - KUMASI ROAD GHANA
PLAN AND LONGITUDINAL PROFILE
Km 245.800 - 246.700 - AS-BUILT DRAWING
COWI
SCALE
1:2500/1:250
DRWG. NO.
2-0301

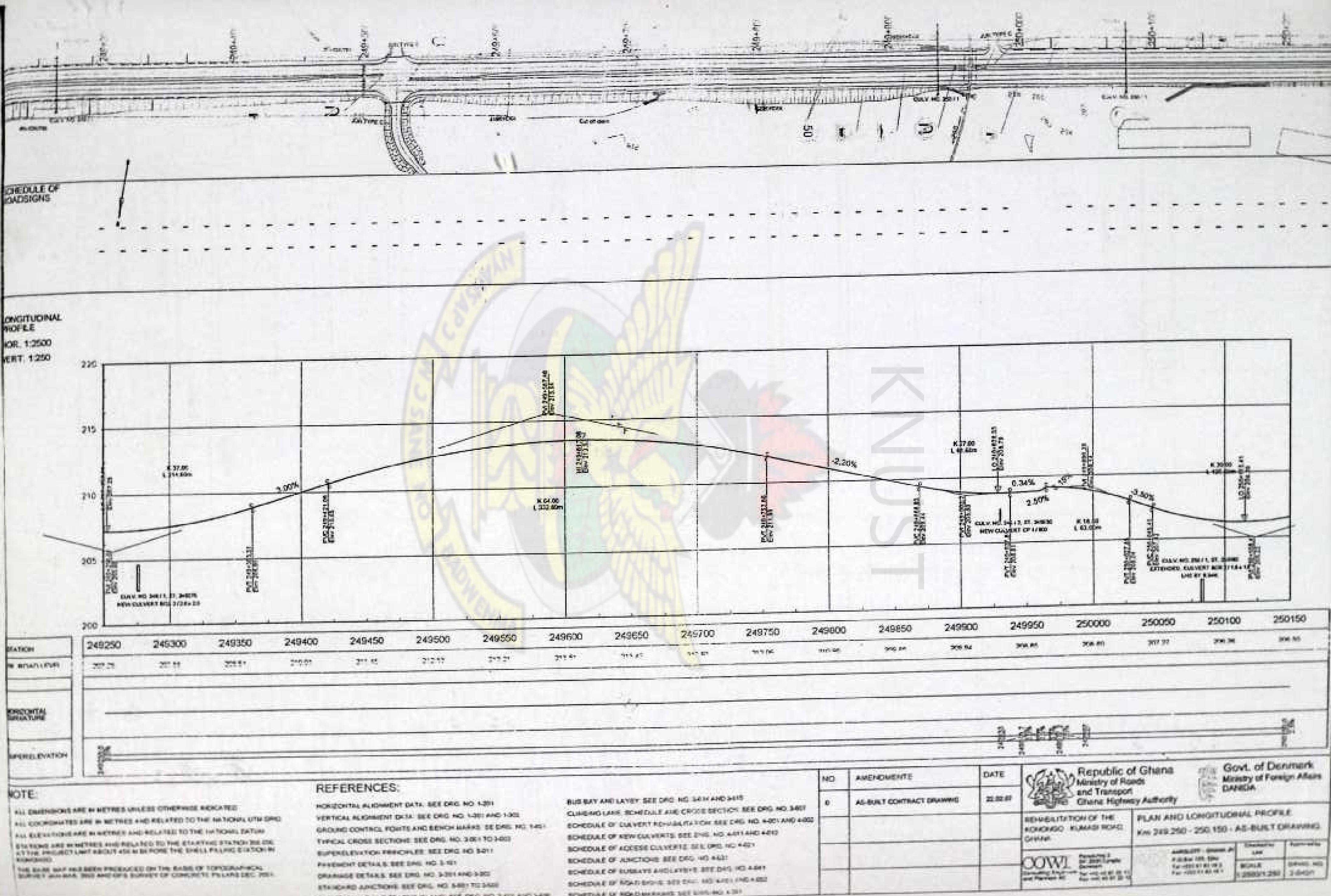


247+400
247+500
247+600
SCHEDULE OF CENTER LINE
LONGITUDINAL PROFILE
HOR. 1:2500
VERT. 1:250
220
215
210
205
200
246700
246750
246800
246850
246900
246950
247000
247050
247100
247150
247200
247250
247300
247350
247400
247450
SUPERELEVATION
REFERENCES:
NO
AMENDMENTS
DATE
AS-BUILT CONTRACT DRAWING
Republic of Ghana
Ministry of Roads and Transport
Ghana Highway Authority
Govt. of Denmark
Ministry of Foreign Affairs
DANIDA
REHABILITATION OF THE KONONGO - KUMASI ROAD GHANA
PLAN AND LONGITUDINAL PROFILE
Km 246.700 - 247.450 - AS-BUILT DRAWING
COWI

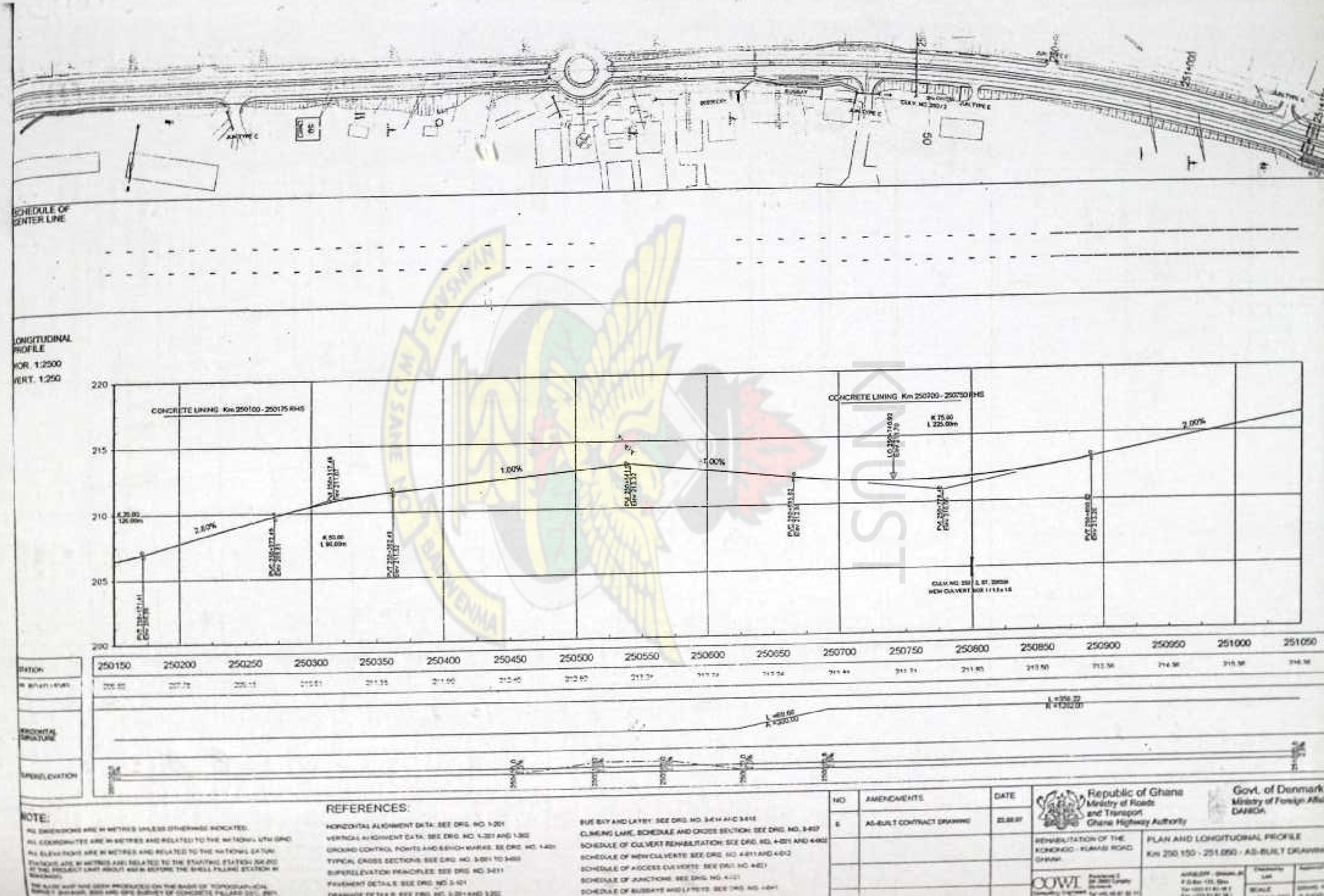


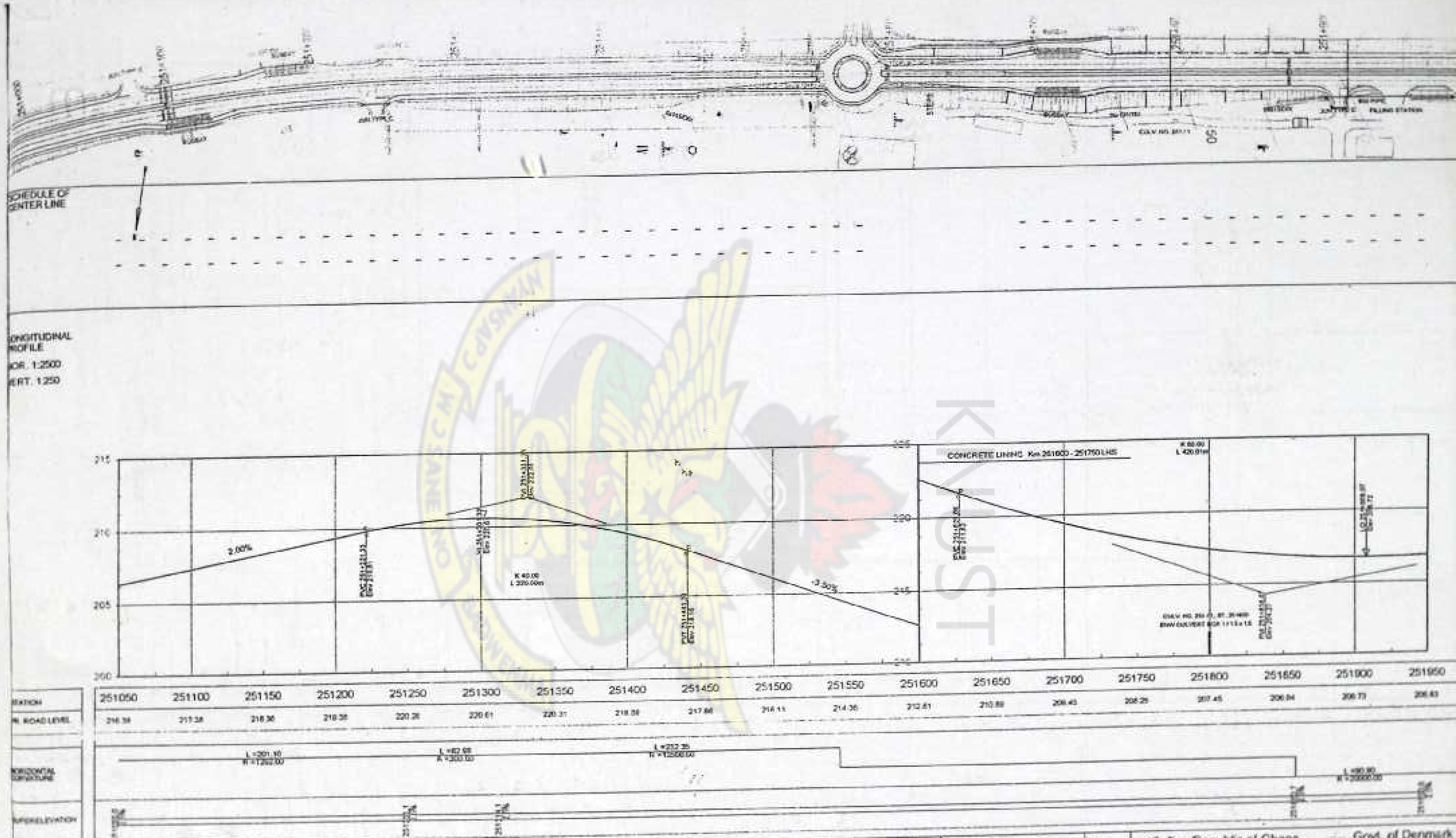
SCHEDULE OF CENTER LINE
LONGITUDINAL PROFILE
HOR. 1:2500
VERT. 1:250
CONCRETE LINING Km 247850 - 247950 LHS
1.00%
-2.80%
K 55.00
L 182.50m
K 64.00
L 467.20m
NEW CULVERT OF 1/600
247450
247500
247550
247600
247650
247700
247750
247800
247850
247900
247950
248000
248050
248100
248150
248200
248250
248300
248350
HORIZONTAL CURVATURE
SUPERELEVATION
L =128.57
A =300.00
L =271.48
R =1100.00
NOTE:
REFERENCES:
HORIZONTAL ALIGNMENT DATA: SEE DRG. NO. 1-201
VERTICAL ALIGNMENT DATA: SEE DRG. NO. 1-301 AND 1-302
GROUND CONTROL POINTS AND BENCH MARKS: SEE DRG. NO. 1-401
TYPICAL CROSS SECTIONS: SEE DRG. NO. 3-001 TO 3-002
SUPERELEVATION PRINCIPLES: SEE DRG. NO. 3-011
PAVEMENT DETAILS: SEE DRG. NO. 3-101
BUS BAY AND LAYBY: SEE DRG. NO. 3-414 AND 3-610
SCHEDULE OF CULVERT REHABILITATION: SEE DRG. NO. 4-001 AND 4-002
SCHEDULE OF NEW CULVERTS: SEE DRG. NO. 4-011 AND 4-012
SCHEDULE OF ACCESS CULVERTS: SEE DRG. NO. 4-021
SCHEDULE OF JUNCTIONS: SEE DRG. NO. 4-031
NO.
AMENDMENTS
DATE
0
AS-BUILT CONTRACT DRAWING
Republic of Ghana
Ministry of Roads and Transport
Ghana Highway Authority
Govt. of Denmark
Ministry of Foreign Affairs
DANIDA
REHABILITATION OF THE KONONGO - KUMASI ROAD
GHANA
PLAN AND LONGITUDINAL PROFILE
Km 247.450 - 248.350 - AS-BUILT DRAWING
COWI


SCHEDULE OF CENTER LINE
LONGITUDINAL PROFILE
HOR. 1:2500
VERT. 1:250
CONCRETE LINING Km 248675 - 249150 LHS
-2.80%
STATION
248350
248400
248450
248500
248550
248600
248650
248700
248750
248800
248850
248900
248950
249000
249050
249100
249150
249200
249250
NOTE:
REFERENCES:
NO
AMENDMENTS
DATE
AS-BUILT CONTRACT DRAWING
Republic of Ghana
Ministry of Roads and Transport
Ghana Highway Authority
Govt. of Denmark
Ministry of Foreign Affairs
DANIDA
PLAN AND LONGITUDINAL PROFILE
Km 248.350 - 249.250 - AS-BUILT DRAWING
COWI



SCHEDULE OF ROADSIGNS
LONGITUDINAL PROFILE
HOR. 1:2500
VERT. 1:250
220
215
210
205
200
3.00%
-2.20%
0.34%
2.50%
-3.50%
K 37.00
K 64.00
K 18.00
STATION
249250
249300
249350
249400
249450
249500
249550
249600
249650
249700
249750
249800
249850
249900
249950
250000
250050
250100
250150
HORIZONTAL CURVATURE
SUPERELEVATION
NOTE:
ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE INDICATED
ALL COORDINATES ARE IN METRES AND RELATED TO THE NATIONAL UTM GRID
ALL ELEVATIONS ARE IN METRES AND RELATED TO THE NATIONAL DATUM
REFERENCES:
HORIZONTAL ALIGNMENT DATA: SEE DRG. NO. 1-201
VERTICAL ALIGNMENT DATA: SEE DRG. NO. 1-201 AND 1-302
GROUND CONTROL POINTS AND BENCH MARKS: SEE DRG. NO. 1-401
TYPICAL CROSS SECTIONS: SEE DRG. NO. 3-001 TO 3-003
SUPERELEVATION PRINCIPLES: SEE DRG. NO. 3-011
PAVEMENT DETAILS: SEE DRG. NO. 3-101
DRAINAGE DETAILS: SEE DRG. NO. 3-201 AND 3-202
STANDARD JUNCTIONS: SEE DRG. NO. 3-401 TO 3-403
BUS BAY AND LAYBY: SEE DRG. NO. 3-414 AND 3-415
CLIMBING LANE: SCHEDULE AND CROSS SECTION: SEE DRG. NO. 3-407
SCHEDULE OF CULVERT REHABILITATION: SEE DRG. NO. 4-001 AND 4-002
SCHEDULE OF NEW CULVERTS: SEE DRG. NO. 4-011 AND 4-012
SCHEDULE OF ACCESS CULVERTS: SEE DRG. NO. 4-021
SCHEDULE OF JUNCTIONS: SEE DRG. NO. 4-031
SCHEDULE OF BUSBAYS AND LAYBYS: SEE DRG. NO. 4-041
SCHEDULE OF ROAD SIGNS: SEE DRG. NO. 4-051 AND 4-052
NO
AMENDMENTS
DATE
0
AS-BUILT CONTRACT DRAWING
Republic of Ghana
Ministry of Roads and Transport
Ghana Highway Authority
Govt. of Denmark
Ministry of Foreign Affairs
DANIDA
REHABILITATION OF THE KONONGO - KUMASI ROAD, GHANA
PLAN AND LONGITUDINAL PROFILE
Km 249.250 - 250.150 - AS-BUILT DRAWING
COWI
SCALE
1:2500/1:250


SCHEDULE OF CENTER LINE
LONGITUDINAL PROFILE
HOR. 1:2500
VERT. 1:250
CONCRETE LINING Km 250100 - 250175 RHS
CONCRETE LINING Km 250700 - 250750 RHS
2.00%
1.00%
-1.00%
2.00%
220
215
210
205
200
250150
250200
250250
250300
250350
250400
250450
250500
250550
250600
250650
250700
250750
250800
250850
250900
250950
251000
251050
STATION
HORIZONTAL CURVATURE
SUPERELEVATION
NOTE:
REFERENCES:
NO
AMENDMENTS
DATE
AS-BUILT CONTRACT DRAWING
Republic of Ghana
Ministry of Roads and Transport
Ghana Highway Authority
Govt. of Denmark
Ministry of Foreign Affairs
DANIDA
PLAN AND LONGITUDINAL PROFILE
Km 250 150 - 251 050 - AS-BUILT DRAWING
COWI



NOTE:

ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE INDICATED.

ALL COORDINATES ARE IN METRES AND RELATED TO THE NATIONAL UTM GRID.

ALL ELEVATIONS ARE IN METRES AND RELATED TO THE NATIONAL DATUM.

STATIONS ARE IN METRES AND RELATED TO THE STARTING STATION [illegible] AT THE PROJECT LIMIT ABOUT 450 M BEFORE THE SHELL FILLING STATION IN KONONGO.

THE BASE MAP HAS BEEN PRODUCED ON THE BASIS OF TOPOGRAPHICAL SURVEY [illegible] AND GPS SURVEY OF CONCRETE PILLARS DEC. [illegible]

REFERENCES:

HORIZONTAL ALIGNMENT DATA: SEE DRG. NO. 1-201

VERTICAL ALIGNMENT DATA: SEE DRG. NO. 1-301 AND 1-302

GROUND CONTROL POINTS AND BENCH MARKS: SEE DRG. NO. 1-401

TYPICAL CROSS SECTIONS: SEE DRG. NO. 3-001 TO 3-002

SUPERELEVATION PRINCIPLES: SEE DRG. NO. 3-011

PAVEMENT DETAILS: SEE DRG. NO. 3-101

DRAINAGE DETAILS: SEE DRG. NO. 3-201 AND 3-202

STANDARD JUNCTIONS: SEE DRG. NO. 3-401 TO 3-403

GHOST ISLAND AND TRAFFIC ISLAND: SEE DRG. NO. 3-405 AND 3-406

BUS BAY AND LAYBY: SEE DRG. NO. 3-614 AND 3-615

CLIMBING LANE, SCHEDULE AND CROSS SECTION: SEE DRG. NO. 3-607

SCHEDULE OF CULVERT REHABILITATION: SEE DRG. NO. 4-001 AND 4-002

SCHEDULE OF NEW CULVERTS: SEE DRG. NO. 4-011 AND 4-012

SCHEDULE OF ACCESS CULVERTS: SEE DRG. NO. 4-021

SCHEDULE OF JUNCTIONS: SEE DRG. NO. 4-101

SCHEDULE OF BUSBAYS AND LAYBYS: SEE DRG. NO. 4-201

SCHEDULE OF ROAD SIGNS: SEE DRG. NO. 4-601 AND 4-602

SCHEDULE OF ROAD MARKING: SEE DRG. NO. 4-301

NO	AMENDMENTS	DATE
6	AS-BUILT CONTRACT DRAWING	[illegible]

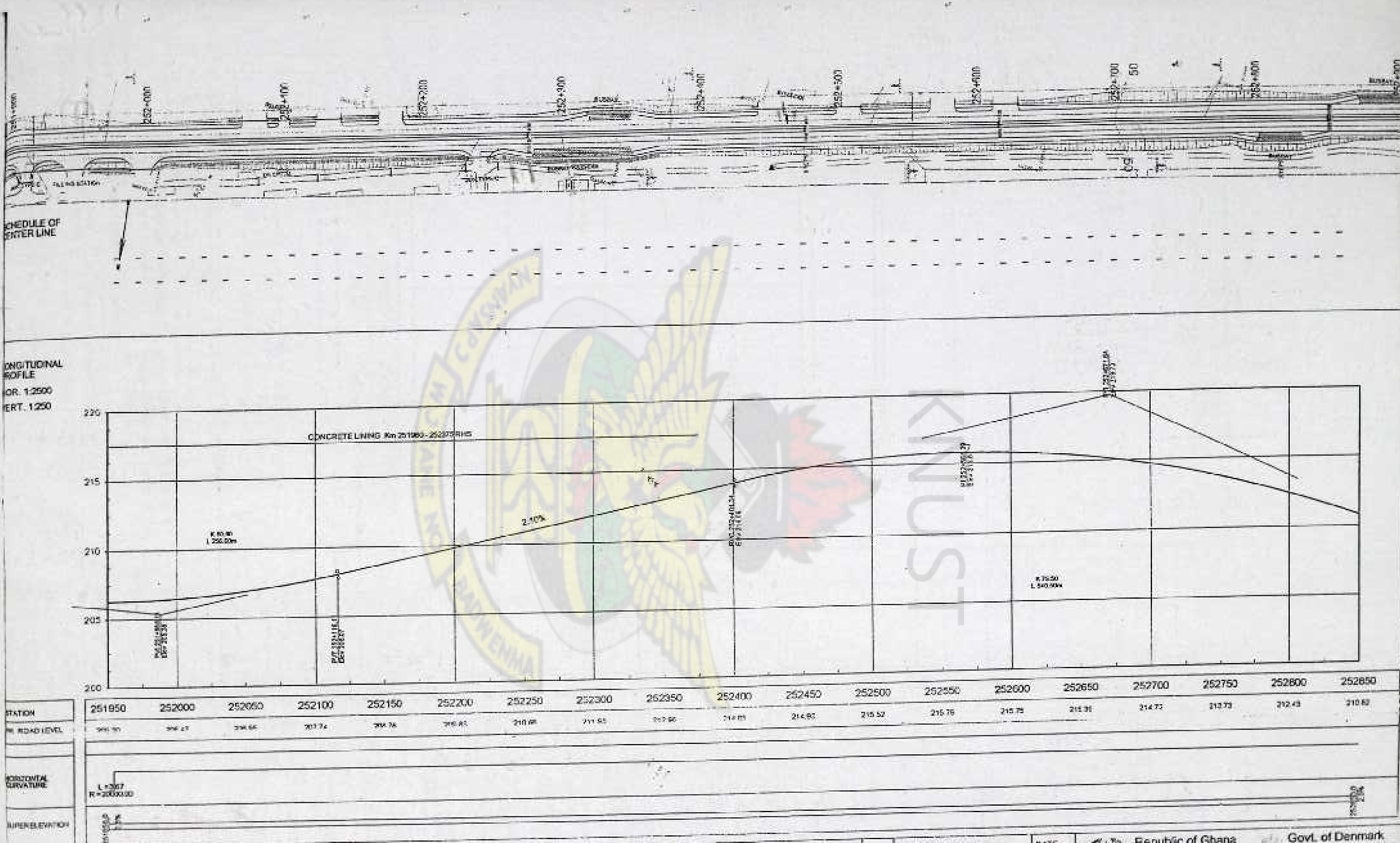
Republic of Ghana
Ministry of Roads and Transport
Ghana Highway Authority

Govt. of Denmark
Ministry of Foreign Affairs
DANIDA

REHABILITATION OF THE KONONGO - KUMASI ROAD GHANA

PLAN AND LONGITUDINAL PROFILE
Km 251.050 - 251.950 - AS-BUILT DRAWING

COWI



NOTE:

- ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE INDICATED
- ALL COORDINATES ARE IN METRES AND RELATED TO THE NATIONAL UTM GRID
- ALL ELEVATIONS ARE IN METRES AND RELATED TO THE NATIONAL DATUM
- STATIONS ARE IN METRES AND RELATED TO THE STARTING STATION 200.000 AT THE PROJECT LIMIT ABOUT 450 M BEFORE THE SHELL FILLING STATION IN KONONGO
- THE BASE MAP HAS BEEN PRODUCED ON THE BASIS OF TOPOGRAPHICAL SURVEY JANUARY 2002 AND GPS SURVEY OF CONCRETE PILLARS DEC. 2001

REFERENCES:

HORIZONTAL ALIGNMENT DATA: SEE DRG. NO. 1-201
VERTICAL ALIGNMENT DATA: SEE DRG. NO. 1-301 AND 1-302
GROUND CONTROL POINTS AND BENCH MARKS: SEE DRG. NO. 1-401
TYPICAL CROSS SECTIONS: SEE DRG. NO. 3-001 TO 3-002
SUPERELEVATION PRINCIPLES: SEE DRG. NO. 3-011
PAVEMENT DETAILS: SEE DRG. NO. 3-101
DRAINAGE DETAILS: SEE DRG. NO. 3-201 AND 3-202
BUS BAY AND LAYBY: SEE DRG. NO. 2-614 AND 2-615
CLIMBING LANE, SCHEDULE AND CROSS SECTION: SEE DRG. NO. 3-607
SCHEDULE OF CULVERT REHABILITATION: SEE DRG. NO. 4-001 AND 4-002
SCHEDULE OF NEW CULVERTS: SEE DRG. NO. 4-011 AND 4-012
SCHEDULE OF ACCESS CULVERTS: SEE DRG. NO. 4-021
SCHEDULE OF JUNCTIONS: SEE DRG. NO. 4-031
SCHEDULE OF BUSBAYS AND LAYBYS: SEE DRG. NO. 4-041

NO.	AMENDMENTS	DATE
0	AS BUILT CONTRACT DRAWING	22.02.07

Republic of Ghana
Ministry of Roads and Transport
Ghana Highway Authority

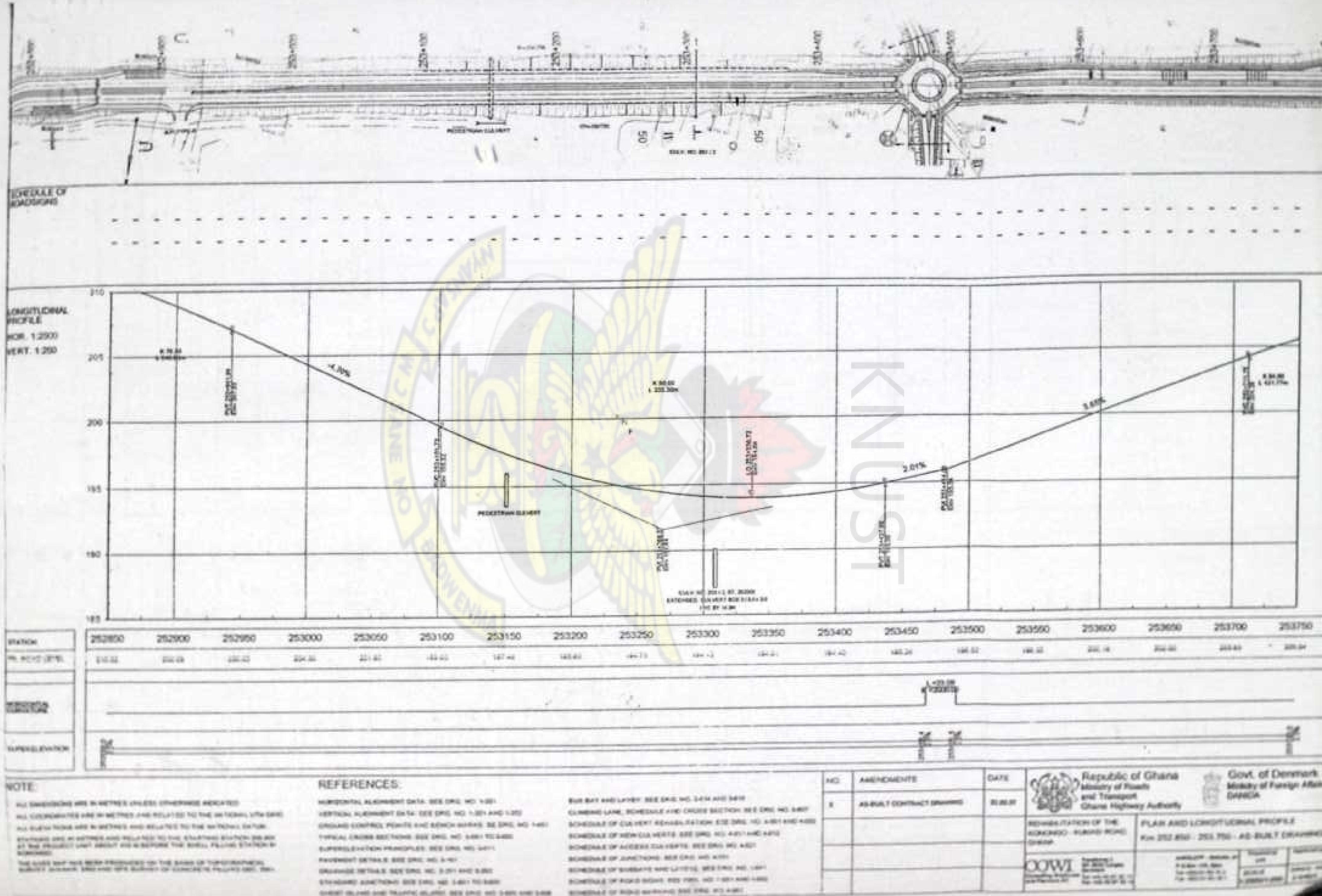
Govt. of Denmark
Ministry of Foreign Affairs
DANIDA

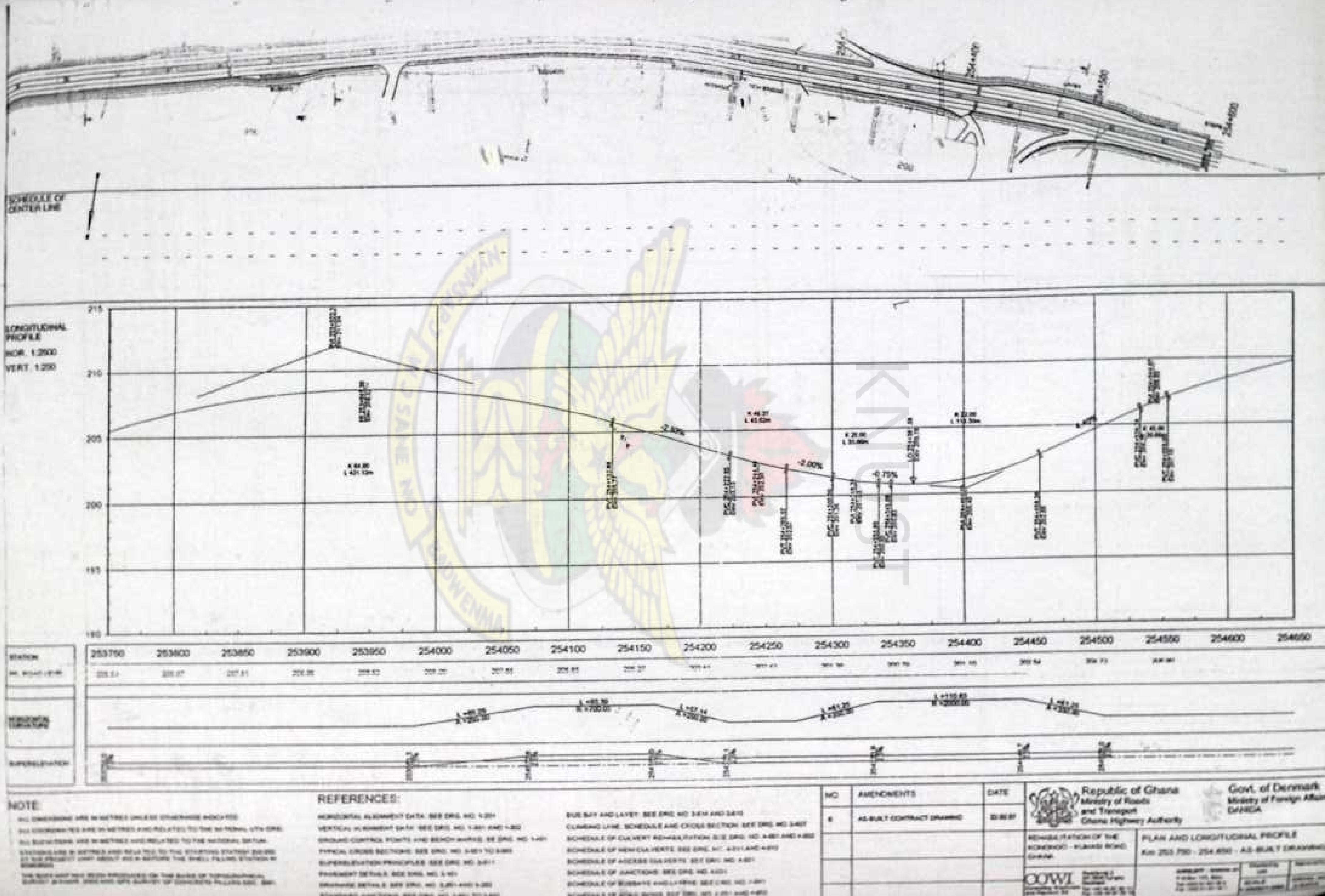
REHABILITATION OF THE KONONGO - KUMASI ROAD
GHANA

PLAN AND LONGITUDINAL PROFILE
Km 251.950 - 252.850 - AS-BUILT DRAWING

COWI

SCALE 1:2500/1:250


SCHEDULE OF ROADSIGNS
LONGITUDINAL PROFILE
HOR. 1:2000
VERT. 1:200
210
205
200
195
190
185
PEDESTRIAN CULVERT
4.70%
2.01%
3.69%
STATION
252850
252900
252950
253000
253050
253100
253150
253200
253250
253300
253350
253400
253450
253500
253550
253600
253650
253700
253750
SUPERELEVATION
NOTE
REFERENCES
NO
AMENDMENTS
DATE
AS-BUILT CONTRACT DRAWING
Republic of Ghana
Ministry of Roads and Transport
Ghana Highway Authority
Govt. of Denmark
Ministry of Foreign Affairs
DANIDA
PLAN AND LONGITUDINAL PROFILE
COWI


SCHEDULE OF CENTER LINE
LONGITUDINAL PROFILE
HOR. 1:2500
VERT. 1:250
215
210
205
200
195
190
-2.50%
-2.00%
-0.75%
STATION
253750
253800
253850
253900
253950
254000
254050
254100
254150
254200
254250
254300
254350
254400
254450
254500
254550
254600
254650
SUPERELEVATION
NOTE
REFERENCES:
NO
AMENDMENTS
DATE
AS-BUILT CONTRACT DRAWING
Republic of Ghana
Ministry of Roads and Transport
Ghana Highway Authority
Govt. of Denmark
Ministry of Foreign Affairs
DANIDA
PLAN AND LONGITUDINAL PROFILE
Km 253.750 - 254.650 - AS-BUILT DRAWING
COWI