His Majesty's Government of Nepal

Road Safety Notes 6

Safety Barrier

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Design Branch, Department of Roads
Ministry of Works and transport

July 1997 Ashad 2054

ROAD SAFETY NOTES

Road Safety Notes are produced by the Traffic Engineering and Safety Unit of the Department of Roads as a means of Increasing road safety awareness amongst highway engineers and' others. Some of the Notes provide Information on aspects 'of. the' road accident situation Nepal, whilst others give detailed technical advice on highway safety measures. The Traffic Engineering and Safety Unit was set up In Balsakh 2052 to provide a road safety and traffic engineering service, and is based in the Design Branch of the Department of Roads at Babarmahal, Kathmandu. The Unit Head (telephone/fax 262 843, e-mail: tesu@dor.mos.com.np) will be pleased to receive comments and suggestions which will help Improve the Road Safety Notes.

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SAFETY BARRIERS

Introduction

Both safety barriers and safety fences are devices which physically prevent vehicles from running off the roadway. However there exists a tiny functional difference between the barriers and the fences: the former do not get deformed in the process, whereas, the latter are designed to absorb some of the kinetic energy by getting deformed. Both types aim to prevent the striking vehicle from gyrating or overturning and, within a narrow angle, redirect it along the direction of traffic movement. For simplicity, the term safety barrier is used to denote both the barriers and fences throughout this technical note.

This technical note will help to determine the necessity of safety barrier along roads and to plan appropriate and cost-effective safety barriers as dictated by site conditions.

Importance of Safety Barrier

Loss of control of a vehicle may be due to several reasons, some of which are hard to be rectified. Safety barrier can greatly reduce the severity of accidents. Its installation lowers accident frequency because of the improved delineation. Therefore apart from introducing other safety measures and improving the road geometry, it is often desirable to install safety harriers along stretches where chances of loss of control of vehicles are higher.

Accident records show that in 83 km Naubise-Mugling section of Pritbivi Highway 38 vehicles overturned and 5 vehicles hit objects outside roadway alone during fiscal year 2052/53. This, resulted in 19 deaths, 39 serious injuries and 137 minor injuries. The severity of some of these accidents could have been reduced if appropriate safety barriers were used.

Criteria for Provision of Safety Barriers

In principle, the following three situations may warrant a safety barrier:

1. To protect vehicles from falling down a slope - this applies where there is a drop of 3 meters or more at or near the edge of the road and the slope is steeper than I in 4.

2. To protect vehicles from hitting a roadside object - this applies where there is a hazardous object, such as a bridge pier, large sign post, breast wall, rocky face, or the end of a bridge parapet which is close to the edge of the carriageway. Conversely, protection of the object from damage by vehicles may also be a reason for installing safety barrier.

3. To prevent out-of-control vehicles from crossing over the central median - this applies on the known crossover-accident locations along a dual carriageway.

However, it is not economic to install safety barrier on every section of road that falls into these categories. There are a number of other factors that need to be taken into account, including:

1. whether there have been run-off-road or crossover accidents at the site - in the case of an existing road

2. whether the site is on a sharp bend - defined as a bend where the design speed (safe speed to negotiate the bend) differs from the approach speed 85th percentile speed by more than 15 km/h.

3. whether it is a busy road - defined as a road with an ADT of >1,000

4. whether the traffic speed (85th percentile speed) approaching the site is greater than 50 km/h.

If two or more of these considerations apply there is probably a good case for installing safety barrier. A bad record of casualty accidents involving run-off-road vehicles (3 or more a year) will in itself be sufficient justification for safety barrier.

Some General Considerations

- A barrier that is too close to the edge of the carriageway can be, a hazard in itself. If it reduces the effective carriage- way width there will be a greater risk of collisions between opposing vehicles, especially on narrow roads. Sometimes however the risk of severe run-off-road accidents may be so great as to justify installing barrier close to the edge, even on the shoulder, if this is the only space available.

- Safety barrier should be placed so that it does not obstruct pedestrian movement, for example the movement of pedestrians to and from bridge footpath. Where there has to be long sections of safety barrier close-to the edge of the running lines, a gap should be left in the safety barrier at least every 30 meters, so that pedestrians can take refuge in it.

- On sections of road where there is often rockfall, gaps should be left in the safety barrier to enable the road workers to push the fallen rock off the road.

- Safety barrier should not interfere with drainage of the carriageway. Solid barriers may need to have drains through them.

- Care should be taken to reduce the risk of a vehicle hitting the end of the barrier, as this can result in extensive damage to the vehicle and severe injuries to the occupants. Probably the best way to reduce the risk is to flare the barrier away from the road edge, and, if possible, bury th6 end in an earth mound.

- Care is needed when barriers of different types have to be connected, especially if one is more flexible than the other. The more flexible one should be stiffened gradually ds it approaches the joint, and, the joint itself must be strong enough to withstand vehicle impacts. The same applies when barrier leads up to bridge parapets.

- Safety barrier should be located so that it is in front of as many roadside obstacles (signs, utility poles, utility cabinets, trees, open drains, etc.) as possible.

- Ends of barrier, and barriers that are located in high-risk situations, should be made more conspicuous by being painted with the yellow and black diagonal bar pattern (solid barriers) or marked with reflective paint (all types of barrier) or fitted with vandal-proof reflectors.

- Proper maintenance of barriers is essential if they are to continue being effective. Moreover, un-repaired damage to barriers may give people the impression that the Department of Roads does not care, so encouraging vandalism.

Types of Safety Barriers

The different systems of safety barriers discussed here are:

Semi-rigid systems
- Steel beam barrier
- Gabion barrier

Rigid systems

- Random-rubble masonry barrier,
- Plum-concrete barrier,
- R. C. C. barrier.

Semi-rigid -systems are generally preferred, especially on high speed roads. They 'give' on impact and this result in less damage to the vehicle and its occupants. Other safety barriers of more flexible system, such as crash cushions and cable barriers are too costly and sophisticated to be used in the present context.'

To aid preliminary design and cost estimation, supply and installation costs of various safety barrier systems in Rupees are given in the subsequent chapters. As some of the barriers are made out of locally unavailable materials and as their prices may vary widely, it is recommended to do a detailed cost analysis before commencing any installation work.

OVERVIEW OF PRESENT PRACTICE

Barriers have been installed in some of the road projects depending upon the intuition and past experiences of the engineer in charge. However due to the absence of standard guidelines, the shapes, sizes and distribution of safety barriers in Nepal vary widely.

Steel Beam Barriers

Steel beam barriers are composed basically of vertical posts and horizontal rails. Other details vary from manufacturer to manufacturer.

This type of safety barrier has been used in some of the sections of Prithvi Highway. The components the barrier are not yet manufactured in Nepal. A typical single-beam barrier costs around Rs 1600 per meter excluding installation.

Fig. 1: Steel beam barrier

Gabion Barrier

Walls of stone filled gabion cages are erected along many roads in Nepal. This type of barrier is constructed by filling stone in the form of dry masonry in the pre-fabricated gabion box. The cross-sectional area of such a box is generally I m x I m. and it is tied horizontally with the other gabion boxes in series by wire. This type of barrier can be easily constructed and maintained. Since the barrier is flexible in nature and anchored in two direction, it effectively retains even loaded trucks.

Supply and erection of gabion boxes costs about Rs 1200.00 per cubic meter at present.

Fig. 2: Gabion barrier

Random Rubble Masonry Barrier

This is simply a random rubble masonry wall in cement mortar. Random rubble masonry barrier can be seen on bridge approaches along Prithvi Highway and Mugling Narayanghat Road. It protects out-of-control vehicles from falling into the river or hitting the end of bridge parapet. This type of barrier costs around Rs 2700 per cubic meter Plum Concrete Barrier

Fig. 3: Random rubble masonry barrier

Plum Concrete Barrier

Since plum concrete is of rigid nature and shows high strength it can be used as safety barrier. Some experimental installation of such barrier has been made along Thankot Naubise Road. However its effectiveness has not yet been established. Plum concrete barrier blocks would cost around Rs 3150 per cubic meter.

Fig. 4: Plum concrete barrier blocks

R C. C. Barrier

Fig. 5: RCC barrier

RCC barriers are useful for the places having less space and a high accident rate. So far, in Nepal reinforced RCC barrier has not been used on road side. However similar construction is in use on DoR standard R.C.C. bridges in the form of barrier kerb,

A pre-stressed version of the barrier can be seen on Mugling-Pokhara Road. The barrier is I only about 500 mm high and thus may only be effective for small vehicles.

Fig. 6: Pre-stressed RCC barrier

RECOMMENDED SAFETY BARRIERS

Steel Beam Barriers

This is the most common type of barrier used in the developed world and it has proved to be very effective. It works by resolving the kinetic energy possessed by an impacting vehicle into components in three dimensions: vertical, parallel to the rail and perpendicular to the rail. The perpendicular and vertical components are dissipated through bending and crushing of

various parts of the vehicle, the beam, plus the support posts and the ground in which they are standing - and so the vehicle is redirected parallel to the rail.

It is a fairly sophisticated system and the design, manufacture and installation should be left to specialists with the necessary skills and experience. If not properly designed and installed the barrier may be ineffective or even hazardous.

Types

There are various types of steel beam barrier in use round the world, but probably the two most suitable for our needs are the Corrugated Beam and the Open Box Beam.

1. Corrugated Beam barrier consists of a "W" section steel beam attached to steel posts by shear bolts. It is effective in containing and redirecting light vehicles traveling at speed (motorway situations) and is probably the most widely used barrier in the world.

   When installed on straight sections, or curves with a radius of 120M or greater, it is usually tensioned between anchorage, as this helps it to rebound the vehicle back onto the road. Figure 7 shows the general arrangement. A barrier of this type made in India is likely to cost Rs 1,600 per meter, excluding freight and installation charges. This barrier is probably too - fight to contain a heavy vehicle impacting at a large angle, though it could be made stronger by adding a second rail (beam) above the first.

2. Open Box Beam barrier is a rectangular section steel beam, usually 150x 200, which is attached to 7" section steel posts. The beam is not tensioned. It is stronger and more rigid than corrugated beam barrier, and so is the best choice for protecting a fixed object which is close to the road edge. To be sure of containing heavy vehicles it is best to add a second rail (beam) above the first. Figure 8 shows the general arrangement.

Specification

Important considerations include:

- Design event: Consider what types of accidents are most likely. A heavy slow-moving vehicle impacting at a large angle needs a different type of barrier from that needed to contain and redirect a first-moving light vehicle impacting at a shallow angle.

- Curve radii: Steel beam barrier will not work well on curves having radii less than 50m. Stronger types of barrier are needed in these situations.

- Ground conditions: If the ground is too soft the posts may not be supported firmly enough

- Barrier height: If the beam is too low the impacting vehicle may roll over the top. If it too high a small vehicle might pass underneath it.

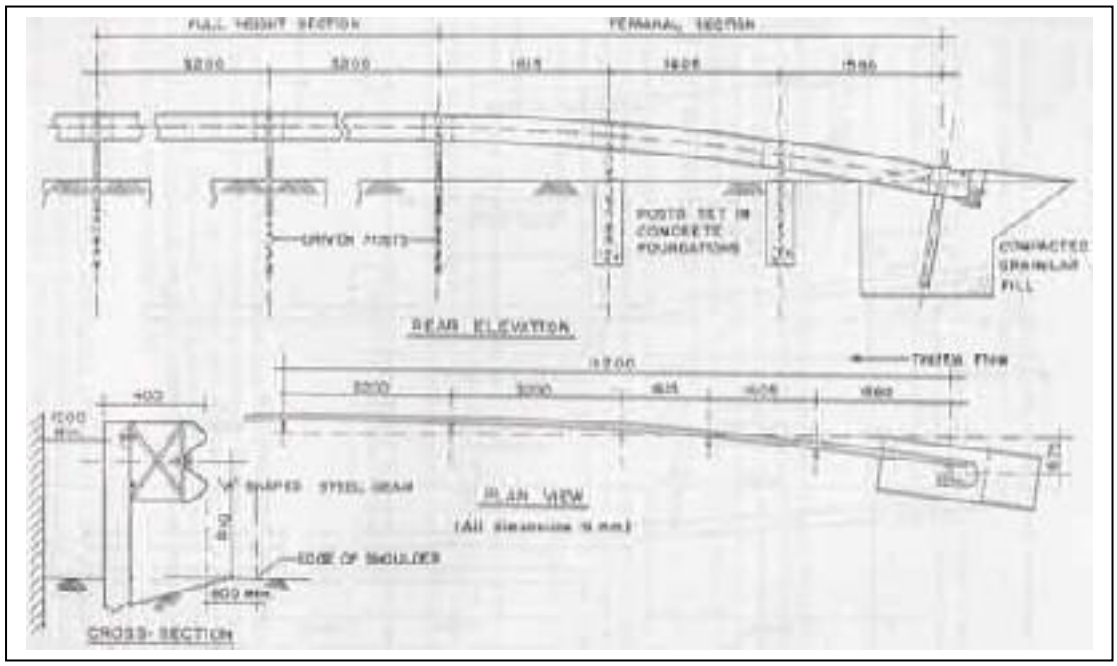

Fig.7: Corrugated steel beam barrier – untensioned (Adapted form UK Highway Construction details, Vol 3, Section 2)

- Clearance available behind the barrier: As some deflect more than others on impact, the type of barrier is determined by the amount of space (clearance) available between the rear of the barrier and the roadside fixed object to be protected.

- Beam joints: The ends of steel beam sections must be overlapped such that there is oncoming traffic.

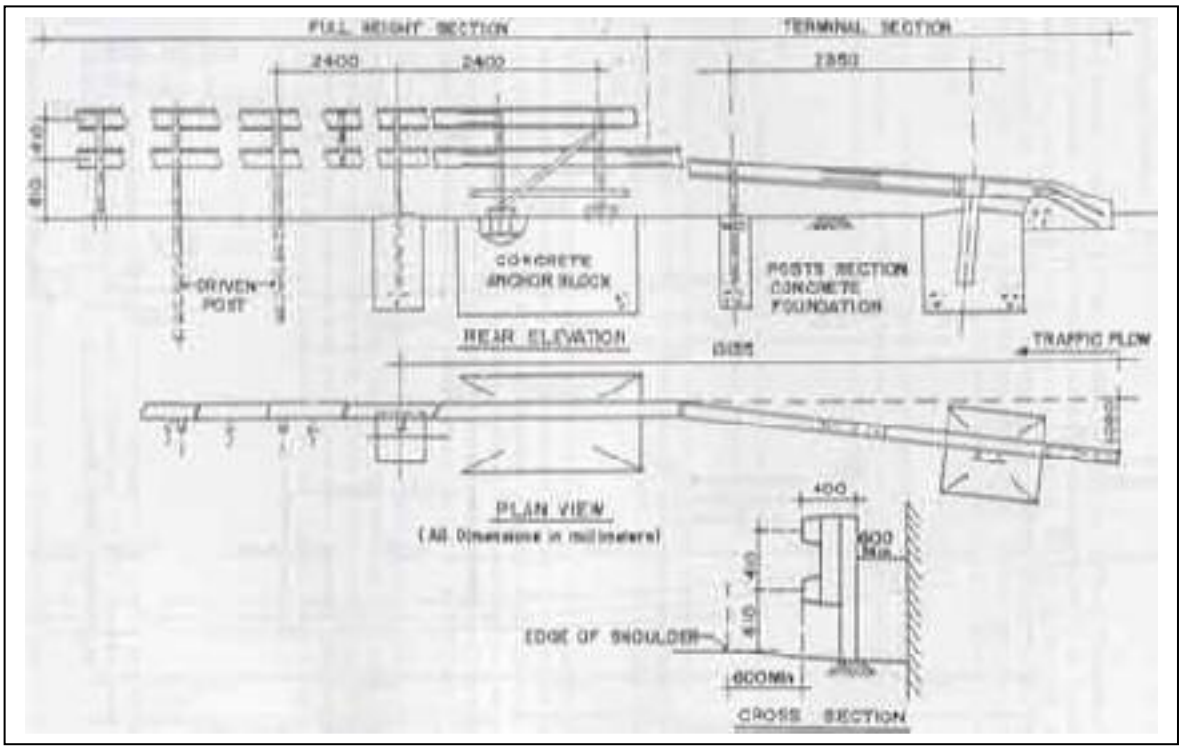

Fig.8: Open box beam barrier – double railed and untensioned (Adapted form UK Highway Construction details, Vol 3, Section 2)

- End protection- To avoid the risk of spearing vehicles on the ends of the beams, the end sections facing the oncoming traffic should be splayed away from the road edge and be ramped down into the ground. Note though that in some circumstances these ramps can launch a vehicle into the air. The other end of the barrier which is facing away from the traffic is best treated in the same way, but, if the risk of impact is low, it can be terminated with an end shoe or "fishtail".

- Connections to bridge parapets: When the barrier leads up to a bridge parapet it is essential that the barrier be stiffened as it gets closer to the parapet, and this is usually achieved by putting the posts closer together (half the normal spacing) and setting them in concrete foundations; it is also vital that the barrier be very strongly connected to the parapet.

Maintenance

Once hit by a vehicle the barrier undergoes elastic and plastic deformations. All the plastic i.e. the permanent deformations should be immediately attended. This may involve reshaping the components using hand tools or replacement of the components when the deformation is excessive. Keeping a good stock of spare parts for repair work is advised.

The foundation of the barrier should be effectively drained. Any missing reflector should be replaced.

Gabion Barrier

Gabion barriers are very effective and at the same time are economic, easy to construct and maintain. However they do not look neat and modem like other types. Gabion safety barriers are useful against all run-off-road type accidents. They have proved to be effective in stopping large vehicles, including loaded trucks. However as they only 'give' on impact but do not redirect the impacting vehicle, there can be a lot of damage to the vehicle and occupants if it is traveling very fast.

Material and fabrication

The material required for gabion safety barriers are stone blocks and galvanized steel wires. The most- common gabion boxes are 1m x 1m in section although other sections could also be made when required. The barrier blocks should be laid continuous for some length. Short sections, with gaps in-between, may not be strong enough.

The gabion netting should be woven with 9SWG wire with double twist and hexagonal opening not bigger than 80xlOO. 6SWG wire should be provided at the edges and after filling the boxes should be tied to each other with 11 SWG wire. The gabion boxes should not be anchored to the ground with steel bars, as it would undesirably stiffen the subsequent barrier wall. Ends of wires should be bent into the wall and should not be left loose. For other details DoR specifications for construction works may be followed.

Application

When used for the protection of bridge trusses and roadside objects, a small gap should be left in-between the object and the barrier to allow for the deformation of the barrier under impact.

Gabion barrier obstructs visibility and requires a lot of space. Thus it is not suitable for use within city limits. However, as the erection of this barrier require only stone blocks and gabion cases, it is encouraged to be used along all other roads.

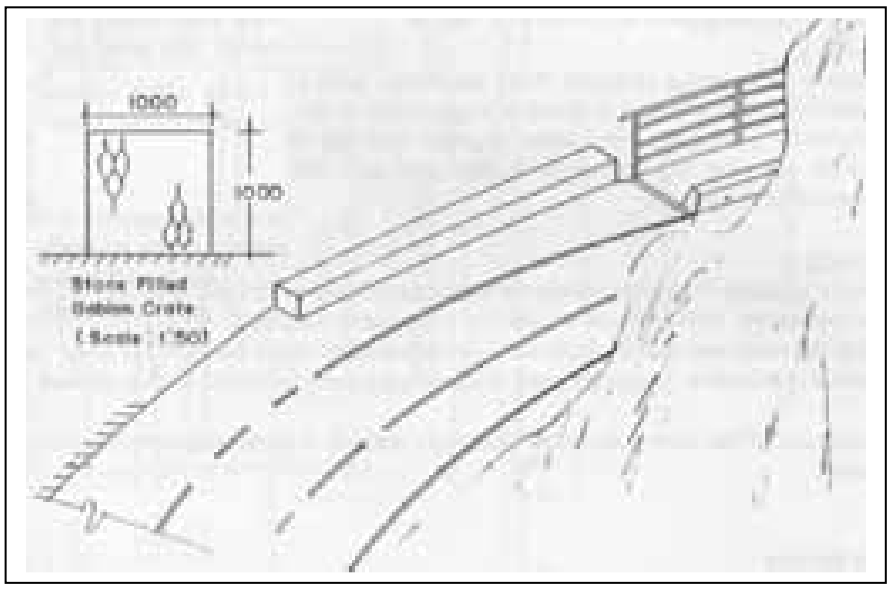

fig. 9: Uabion barrier

Maintenance

Any change in shape or damage of the barrier under impact of striking vehicles should-be rectified immediately afterwards. If the deflection is excessive, the boxes should be emptied, brought to shape and then refilled with stone blocks.

The barrier should be checked regularly even if they are not hit by vehicles. If the wires are coming apart or if stone blocks have come out of the mesh opening due to vandalism or some other reason, necessary repair work should be done. Eventually, the barrier will have to be completely rebuilt but the cost should not be great because the stone will still be there.

Random Rubble Masonry Barrier

It is to be noted here that the Frequently used 1000 to It 500 long "confidence blocks" on the road side, though made out of random rubble masonry, do not serve as safety barrier. To serve as a barrier the wall should be longer than the front of common trucks and buses and be much more solidly built.

Material and construction

The barrier should have a good foundation. The height and the width should not be less than 1000 and 700 respectively. DoR standard specification may be referred for material and method of construction.

Application

Random rubble masonry barrier is mainly suitable to block the gap on the approaches of bridge, especially over side drain. It should be painted as shown in figure 10 with slanting black and yellow alternating strips.

Fig. 10: Random rubble masonry barrier with confidence blocks in foreground

Maintenance

Being a rigid structure it can withstand smaller impacts and does not need maintenance often. However in case of major collision, damaging the wall permanently, reconstruction or replacing it with other barrier types may be required.

Plum Concrete Barrier

This barrier is a compromise between random rubble masonry and RCC barrier. Plum concrete barrier is stronger than the former and at, the same time costs less than RCC barrier.

Material and fabrication.

Plum concrete is prepared by mixing a maximum of 40 percent of stone blocks with 1:2:4 cement-sand-gravel mix. The size of the blocks should not be more than 200 mm. For other details DoR standard specification may be referred.

To obtain necessary inertia to stabilize the impacting force of a loaded truck the barrier blocks should be at least 3000 mm long and 750 mm high. For other dimensions figure I I may be referred. The gap between the blocks should not be more than 1500 mm wide.

Application

Although the effectiveness of plum concrete barriers are not yet fully established, they are supposed to provide enough safety at some specific locations.

Similar to gabion safety barriers,~ these barriers do not redirect the impacting vehicle. Moreover they obstruct visibility and require a lot of space. Thus plum concrete barriers are not suitable for use on narrow urban roads. These barriers may be erected along all other

roads where the availability of cement is better than that of gabion wire and where chances of vandalism are higher.

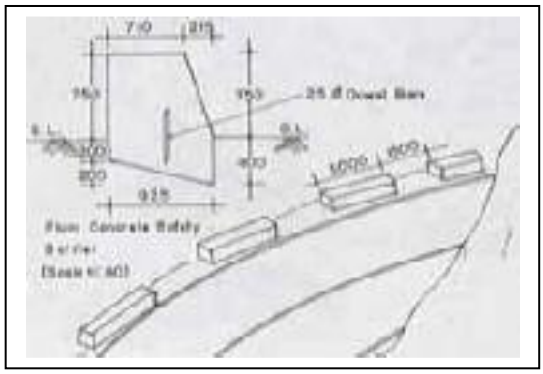

Fig. 11: Recommended dimensions concrete barrier blocks.

Maintenance

Apart from ensuring drainage of foundation, these barriers require little maintenance once installed.

R C. C. Barrier

A properly shaped RCC barrier physically prevents errant vehicles from going off the road and tend to divert them back into their traffic lane.

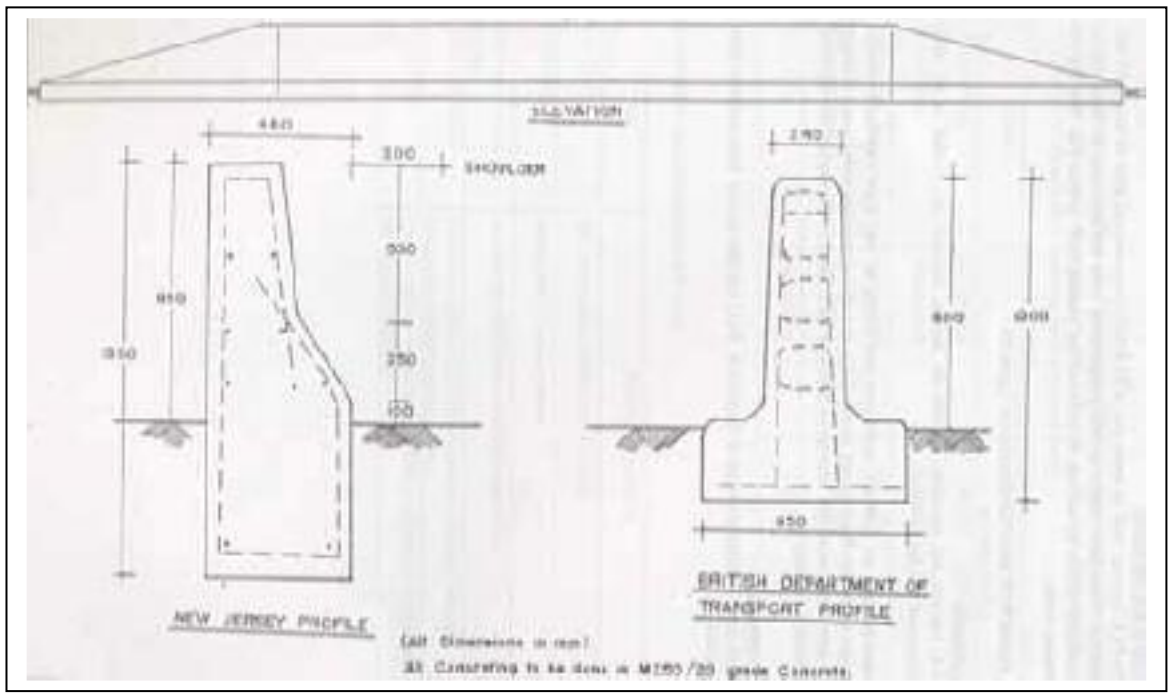

Fig.12: Alternate types of RCC barrier

Material and fabrication

The RCC barriers shall be made out of M ~50/20 concrete and shall be laid on M 70/1000 concrete. Some shear reinforcement is required to resist the impacting force. The depth of foundation should be enough to mobilize the passive earth pressure so that the barrier remains stable.

A typical RCC barrier is illustrated in figure 12.

Application

RCC barriers are primarily suitable for median barriers on divided roads or as a component of a bridge barrier.

These barriers are normally continuous and belong to very rigid systems. With smaller impact angles the 'New Jersey' profile helps to redirect vehicles without serious damage, but may cause some light vehicles to overturn. RCC barrier with vertical faces are gaining popularity nowadays.

Maintenance

Apart from ensuring drainage of foundation, RCC barriers require little maintenance once installed.

COST ESTIMATION

To get an preliminary idea on the cost of the barriers, the following table may be referred. However as the prices are dependent on many factors, a detailed cost analysis is recommended to be done before finalizing for a particular barrier.

Barrier	Layout	Cost per 100m of Road protected(NRs)
Steel beam barrier	Continuous	1,60,000 (CIF Birgaunj)
Gabion barrier	Continuous	1,20,000
Random rubble masonry barrier	Continuous	2,03,000
Plum concrete barrier	Continuous	1,90,000
R.C.C barrier	Continuous	3,00,000

SUMMARY OF RECOMMENDED USE

Barrier	Recommended Use
Steel beam barrier	High speed roads; where space is limited
Gabion barrier	General use: but not in towns
Random rubble masonry barrier	Alternate to other barriers on bridge approaches
Plum concrete barrier	Alternate to gabion barrier where a more permanent looking structure is required slower speeds
R.C.C barrier	Narrow medians; where space is limited; where it is essential that the vehicles to stopped