



Ministry of Road Transport
and Highways
Government of India

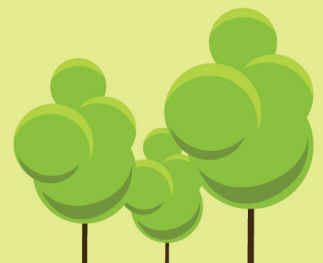


PLANTATIONS

As A Tool for Road Safety



Green Highways Division
National Highways Authority of India







NITIN GADKARI

Minister of Road transport, Highway,
Shipping & Water Resources &
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FOREWARD

Trees and plants are one of the most precious gifts of nature to the mankind and they are an innovative technology on their own. Efforts should be made in the direction of adjusting anthropogenic techniques and design to conform to that of nature and get the best out of it. Instead of solely trying to balance economic activities and environment protection, one should integrate environment protection and enhancement as a part of it. In terms of highways, plantation shall be taken up as a technology for road designing.

Building road, builds the economy of a nation but building safer and greener roads boost healthy economy. Roads are valued and shared assets that provide accessibility, promote trade and tourism, and bridges geographical divide. It is the responsibility of the highway fraternity to join hands in building and maintaining safer and greener roads. To address this, Ministry of Road Transport and Highways has recently promulgated the **Green Highways (Plantations, Transplantations, Beautification and Maintenance) Policy - 2015** and established the **Green Highways Division** for developing green corridors along the National Highways contributing towards better environment and meeting the CoP 21 commitment of India. This document will provide a kick start towards planning and implementation of using plantation as part of road design, particularly with respect to safety.

It is needless to say that India has a rich pool of engineers and environmental experts and I am confident they will contribute together towards realization of the objective to integrate plantation as a safety tool for roads. I also congratulate the team of GHD for taking the first step towards it.

(NITIN GADKARI)





Preface

Green Corridor Development is an integral part of the National Highways. The Greening along NHs not only contributes towards environmental and aesthetic values of the NHs, but is also conducive for the commuters for safe and pleasant driving. The Green Highways Policy of the Ministry of Road Transport and Highways, Government of India, is a landmark initiative for sustainable environment and inclusive growth, and towards fulfilling India's assurance for creating additional carbon sink of 2.5 billion metric ton under Cop 21 commitment. The policy envisions a progressive approach to involve all stakeholders in the development of green corridors along NHs.

Green Highways Division (GHD) under National Highways Authority of India (NHAI) is effectively pursuing the task of planning, implementation and monitoring of green corridor development along National Highways. GHD is committed towards promoting innovative and environment friendly measures for greening of highways.

There is necessity of making continuous efforts to explore and improvise various technological advantages of greening that can create an integrated network of highways and green corridor. GHD has successfully attempted to integrate significant studies and practices of other countries in Indian conditions to substantiate the fact that the plantations along NHs as an integral system can be effectively used as road safety tool. This handy document has been developed by the experts in this field as a thriving endeavor in this direction.

With the support of all stakeholders, GHD should continue to explore pioneering ideas and ultimately innovate the green corridor concept as an integral system of NHs for effective road safety measures.

(Sanjeev Ranjan)
Chairman, NHAI





MESSAGE

National Highways Authority of India (NHAI) has created Green Highways Division (GHD) and has entrusted the task of planning, implementation and monitoring roadside plantations along National Highways. Green Highways Division is committed towards encouraging adoption of environment friendly measures for highways. As part of the same, GHD is continually exploring on various technological benefits of plantation that can help create an integrated network of highways and green corridor. There are several studies and practices in other countries that uses plantation of trees, shrubs, vegetative ground cover to develop an integral system of road side drainage, ground water recharge, anti-glare screen, reduce road surface temperature, use as safety tool etc. This particular document has been developed by the experts in this field as an effort in the same line.

Under the able guidance of the Hon Minister, MoRTH, GHD will keep on exploring innovative ideas and ultimately help to reduce the ecological as well as carbon footprint of highways in India.

(D O Tawade)
Member Technical, NHAI





PROLOGUE

As per the proceedings of Workshop on "Innovations on Green Highways", it was recommended to develop a scientific paper for establishing that Plantation is a recognized safety tool for road users. This is an information based white paper developed to set off the note towards incorporation of plantation as an engineering element instead of considering it as a problem while designing roads.

This document has been prepared using the innovative and practical knowledge pool of experts working in the highway fraternity as air pollution expert, safety expert, highway engineer, horticulture and biodiversity experts and environmental planner from various organizations like GHD, CSIR-CRRI and DPR consultants.

It is expected that this document will act as a logical base for abolishing the taboo of trees being considered as a hazard for road users and get all stakeholders' together to come up with innovative ideas and research work on how the goodness of trees/ shrubs can be utilized as part of road designing.

The document scientifically proves that the concept of Green Corridor development along the National Highways will not only add to the environmental and aesthetic values of the Highways, but will significantly contribute towards the road safety processes, as effective supplementary and complimentary measures.

Dr Ajoy K Bhattacharya
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Author's Disclaimer:

The Author has generously borrowed, quoted and adapted from cited references. The author has formulated some innovative measures towards incorporation of plantation into road design as a tool for safety. Technical or engineering feasibility of the same will have to be established on case to case basis. Any unintended error is regretted.

Any feedback / suggestion to this document is welcome.



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1. INTRODUCTION

Road traffic accidents in India are emerging as the major cause of death and injury with subsequent disability and burden on economy and strength of the nation. The economic damage due to road accidents results in more than 3.7% loss of national GDP of India (Sharma, 2016). Statistics reveal that out of total road accidents in India around 4.5% happen due to the fixed objects, trees, level crossings, non-motorized vehicles etc (MoRTH, 2015). Though there is no clear statistics in India that can reveal the share of accidents caused due to trees, trees have been entrusted the same status of being as hazardous as are any other concrete structures or fixed objects along the roads. Hence, there is a need to develop a deeper understanding of how trees can be integrated into a safe roadside environment and whether trees actually lead to accidents or prevent vehicles from colliding into road side land user or toppling down as may be the case in hilly areas or high embankments. There are several instances of vehicles being saved and damage reduced owing to the presence of road side vegetation. As colliding of vehicles into road side land users like vendor shops, hawkers and residences may cause additional damage to life and property. It is also required to explore that trees have some inherent technological benefits and can act as a mental & physical restorative factor for drivers and reduce accidents.

2. RATIONALE BEHIND CONSIDERING PLANTATION AS A SAFETY TOOL

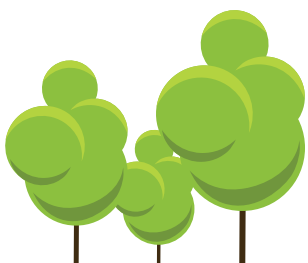
It is a long drawn taboo that trees along the roads or highways are dangerous for human life. Basically, Road side plantation can either prove to be a hazard or a tool for safety of road users based on their positioning, management and choice of species. Although at present date there are relevant IRC codes/ guidelines available defining measures that could reduce the risk of accidents due to plantation (and shall be followed), this taboo somehow creates a sense of negativity amongst the stakeholders and discourages plantation.

It shall also be noted that trees along the road side are less hazardous as compared to any other concrete structure or road furniture along the roads. It is the driving quality, driver's behavior, pavement condition, speed, vehicle condition etc. that cause the vehicles to run off the road and hit an obstruction, be it a tree or an electric pole or any other concrete structure. The current engineering solutions are constrained by a narrow understanding of potential

According to the Oxford Dictionaries website, a tree is 'a woody perennial plant, typically having a single stem or trunk growing to a considerable height and bearing lateral branches at some distance from the ground'²

²According to the Oxford Dictionaries website, a hedge is "a fence or boundary formed by closely growing bushes or shrubs." A tall hedge can also be made up of trees. Hedges consist of more than one shrub and have different uses. Hedges provide privacy screens, fences, visual boundaries, windbreaks and different shapes to add interest to landscaping.

³Shrubs are woody plants with more than one stem and a mature height of less than 15 feet. Shrubs can be deciduous or evergreen and range in size from creeping along the ground to 15 feet tall. Shrubs can be left to grow naturally or they can be pruned and shaped.





contributions of the plantation to the safety of the roadside environment and their role in its design. Also, when talked of plantation, it is majorly talked about tree plantation and very less of shrubs and hedges. It is required to explore how trees¹/ hedges²/ shrubs³ can be effectively incorporated into a safe roadside design that integrates engineering, community values, and environmental amenities. There is a need for research further on plantation as another roadside technology.

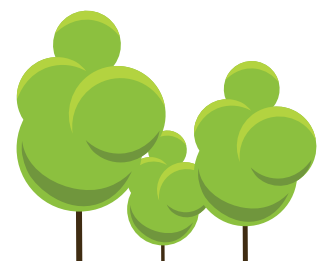
To account for safety, it is recommended in IRC codes (viz. IRC:SP:84-2014, IRC:SP:87- 2013) that 'trees shall not be placed within 14m of the center line of the extreme traffic lane to provide recovery area for vehicles that run off the roads'. It is also mentioned in the above referred IRC codes that - 'where the concessionaire intends to use an alternative to these Standard Guidelines for delivering an equal or better product, he shall be permitted to use such alternative subject to the following conditions: 1) He shall demonstrate that the proposed alternative conforms to any of the following. 2) American Association of State Highway and Transportation Officials (AASHTO)'. Further, AASHTO guide to flexibility in highway design (AASHTO, 2004b) notes that "while clear zone dimensions are provided ..., they should not be viewed as either absolute or precise. It is expected that ... the design of the roadside is a site or project specific task for the designer... [and that] more than one solution may be evident or appropriate for a given set of conditions (Wolf, 2005).

Keeping in view the above clauses and a fact that plantation has enough good to do to the road users, possibility of inclusion of hedges (with selected shrub species) into the road design to act as safety tools or supplementary to existing safety features has been explored in this document.

3. AIM & OBJECTIVES

This is an information based document that aims to put forth how plantation can be effectively used as a tool for road safety keeping in consideration the relevance of measures and guidelines recommended in various codes to reduce the risk emerging from road side plantation. The objectives are to-

- Review existing IRC codes/ manuals and find out where hedges/ shrubs can be incorporated to enhance safety features.
- Review Road Safety Audit reports and find out the gaps that can be addressed through hedges/ shrubs
- Identify measures that can be further elaborated and argued upon by different stakeholders and thus set the note to further incorporate these provisions into codes.



4. DETAILS OF VARIOUS MEASURES

4.1 PLANTATION AS A SUPPLEMENT TO FLEXI-CRASH BARRIER! CRASH ATTENUATOR

41.1 Concept

It is required by IRC codes viz. IRC: SP: 87-2013 to leave a setback of 1m between the flexi crash barrier and the start of drop of embankment. Shrubs can be planted to act as cushion on the embankment below the sub grade layer (Figure 1) using hydro seeding or manual seeding technique. Shrubs shall be planted below the subgrade layer as otherwise the roots may damage the drainage (granular) layer. Also it would be necessary to sow seeds manually or carry out hydro seeding instead of planting saplings as it would result in digging of pits and in turn damage the embankment. Also precaution shall be taken not to damage the road side drains at the toe of the embankment.

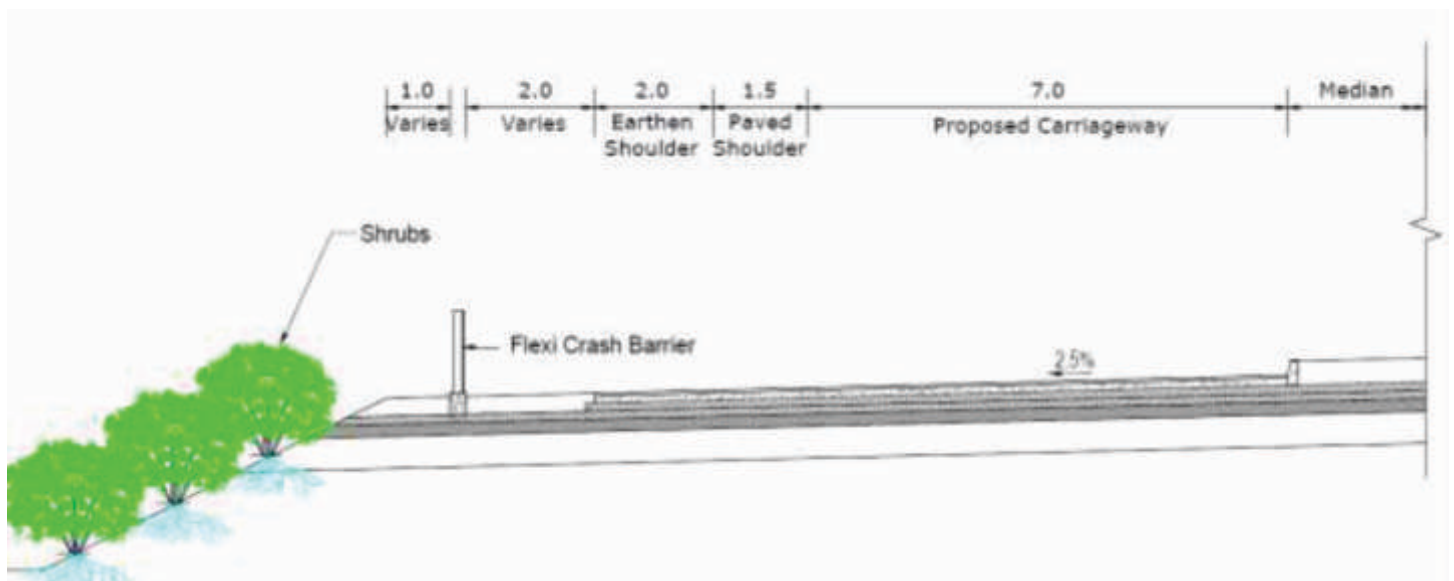
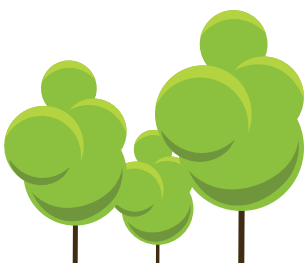


Figure 1- Plantation of shrubs below sub grade level on embankment to act as a supplement to flexi-crash barrier (indicative drawing)

Hedges can be also planted between potential hazard and flexi-crash barrier to provide extra cushion. Width and height of shrubs would depend on nature and height of hazard and availability of space (Figure 2).



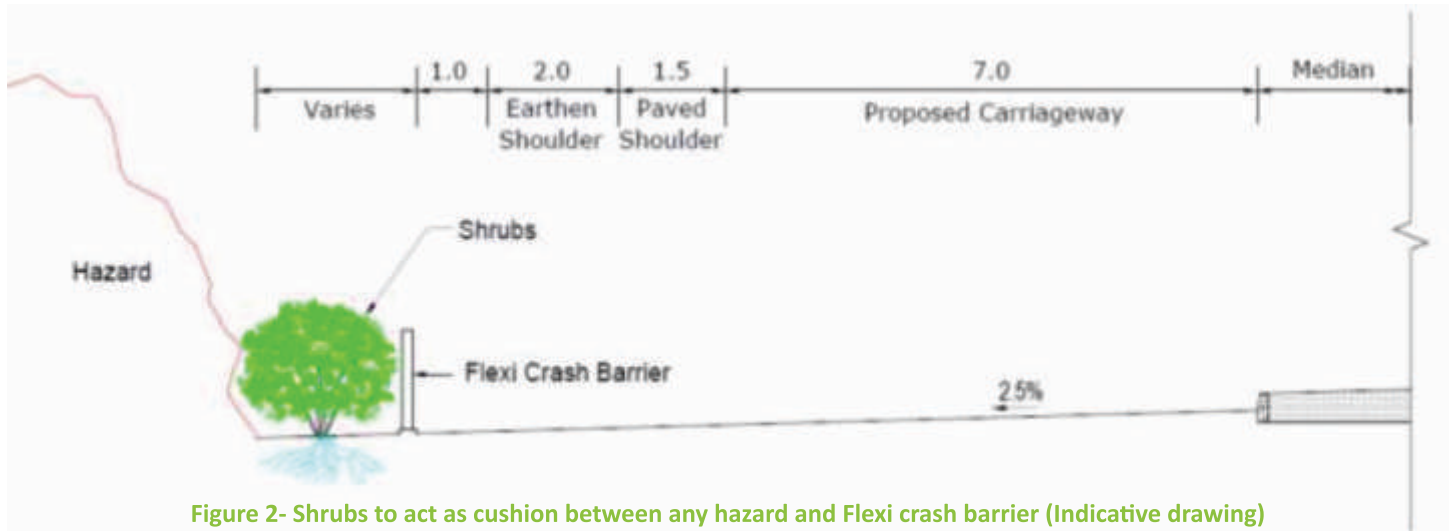


Figure 2- Shrubs to act as cushion between any hazard and Flexi crash barrier (Indicative drawing)

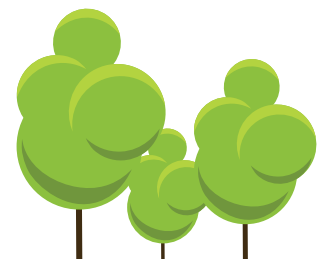
In case of cut slope along the roads, shrubs can be planted along the slopes that can act as cushion in case of vehicle collision. For example, Figure 3 shows a toppled truck in Mumbai-Pune Expressway (SLF, 2015). Apart from wide shoulder had there been shrub cushion along the shoulder, damage to the vehicle/user could have been reduced. Shrubs / hedges with dense foliage of not more than 1m height (so as not to obstruct visibility for car drivers) can be planted in place of crash attenuator that can reduce crash severity by decreasing the rate of deceleration of the vehicle. Figure 4 shows a crash of a vehicle on a concrete structure on Mumbai-Pune Expressway. This could have been avoided if a crash attenuator like W-beam fender panels supported with diaphragm or sand barrels had been in place (SLF, 2015). Here, the possibility of replacing crash attenuators by hedges can be explored based on site-specific conditions (Figure 5 & 6).



Figure 3: Truck driver wanting to park his truck on the shoulder did not notice the narrowing shoulder. Truck toppled over to the left



Figure 4: Crash with concrete structures on road side



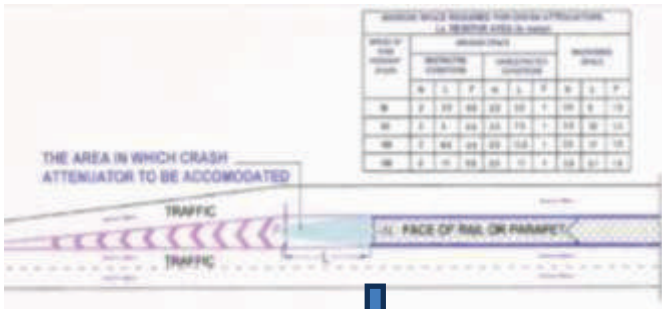


Figure 5 Space required for crash attenuators (IRC: SP: 84-2014)

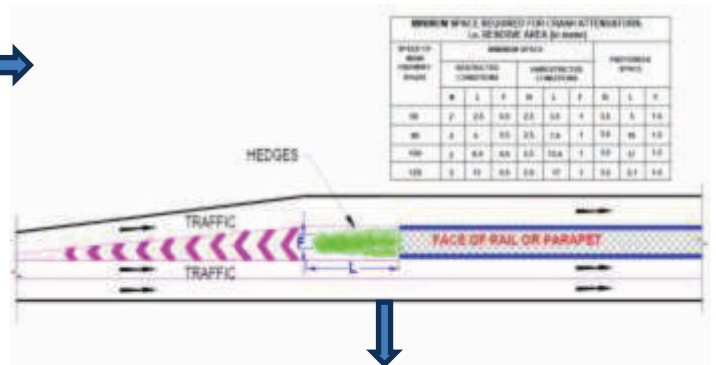


Figure 6 Plantation of shrubs along with flexi wire crash barrier can be explored (indicative)

Often unguarded bridge/ flyover pillars also lead to fatal collision of vehicles and accidents (Figure 7). Here again tall hedges can be planted along the pillars to act as cushion. An additional installment of plastic coated wire mesh hooked at top of the pillar would be necessary to prevent branches bending over the traffic way (Figure 8, 9).



Figure 7- Crash with overhead bridge pillar

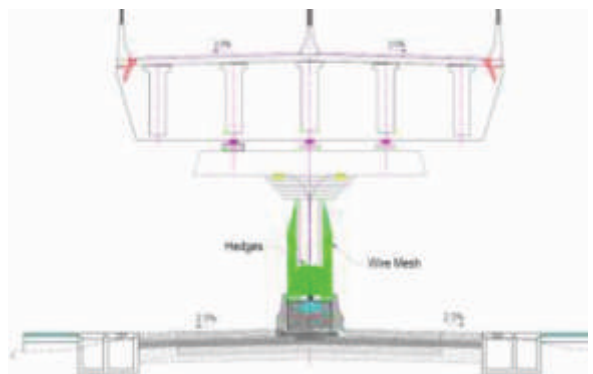


Figure 8- Hedge along pillars to act as cushion (indicative)

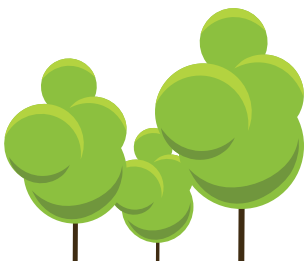




Figure 9 Hedge along pillars acting as cushion in Elevated Expressway, Nashik

Median with the width of more than equal to 3 m shall be used for plantation of one row of shrubs and in median of width 5m shall be planted with two rows of shrubs instead of using any kind of concrete structures, so that it can act as cushion in case of vehicle collision. For instance, flower pots placed in the median of Mumbai —Pune Highway caused crashing impact on car as shown in Figure 10. Instead of flower pots or any other kind of concrete structures, plantation could have proved to be a better option in such a case (Figure 11).



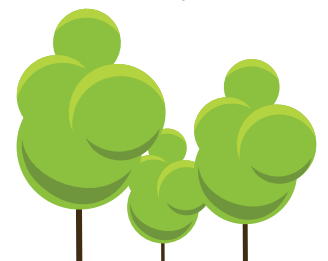
Figure 10-Impact on car due to flower pots placed in median- Mumbai Pune Expressway



Figure 11-Shrubs can be planted instead of pots in medians of to act as cushion & Ant glare-NH 44, Nagpur Hyderabad Expressway

It may be noted that safe stopping site distance of 180m and intermediate/ minimum desirable sight distance of 360 m corresponding to the designed speed of 100 km per hour shall be ensured on all curved sections, on the innermost lane of the curve and cross road sections for 2-lane/ 4-lane / 6-lane roads as per IRC: SP-73: 2015 & IRC: SP: 84-2014 and IRC: SP: 87-201a

Shrubs species shall be selected based on the nature of plants, climatic condition, type of soil, availability of water, purpose and origin of species. A list of suggested species is given in Table 1.



4.1.2 Maintenance

Apart from maintenance and monitoring recommendations made in IRC: SP: 21-2009 and Green Highways (Plantation, Transplantation, Beautification and Maintenance) Policy, 2015, following additional maintenance will have to be done for hedge/ shrubs planted for safety purpose:

- Watering shall be through drip irrigation system especially in the median to avoid water & soil spillage on road, prevent damaging of pavement due to water seepage and also prevent wastage of water.
- In case of vehicle collision a portion of the plantation safety barrier might get damaged viz. breaking, bending of stems, uprooting of shrubs etc. In such case a temporary barrier of sand barrels or wire fencing shall be done for the time required for the vegetation to regrow. Staffs shall be trained to take care of damaged hedges. Bent gem to be supported by timber pole, manuring and watering to be done timely.
- Pruning of such hedges shall be done periodically to prevent the branches from obstructing space of shoulder and carriageway. Pruning timing shall be based on the growth pattern of the particular species. Institutional arrangement for maintenance is as given in point no. 4 of this document.

4.2 PLANTATION TO REDUCE DIRECT TREE-VEHICLE CONFLICTS

4.2.1. Concept

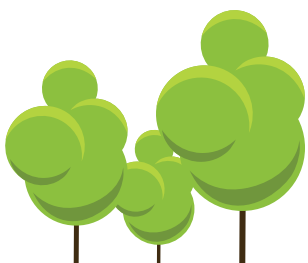
Earlier tall trees use to be planted along the highways to provide shade. Later keeping in view high speed highways and safety as mentioned in para 8.11.2 of IRC: SP:21-2009, it was suggested to plant small and medium ornamental trees in the 112 row. Presently keeping in view the increasing tree-vehicle collision (Figure 12) cases, it is suggested to plant hard hedges or shrubs of 1.5 to 2m height and minimum 1.5 m width in the 1g row or in front of the 1g row of trees. The hedges will act as a cushion (Figure 13 &14) between tree gems and vehide hitting it thus is fikelv to cause lesser damage to the rider s life, vehicle aswell as the trees. Hedge I shrub species shall be so chosen that the lateral spread of their roots does not damage the pavement and are native to the road site.



Figure 12 Collision of vehicle with tree



Figure 13 Plantation of shrubs along with flexi crash barrier can reduce vehicle tree collision



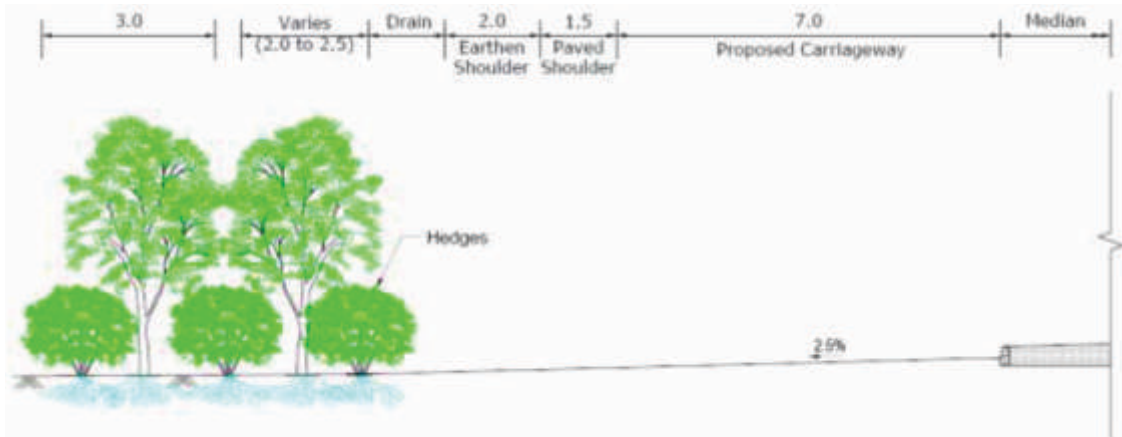


Figure 14- Hedges to act as cushion to reduce damage due to vehicle - tree collision

This will be generally applicable in the rural or open country sections on roads at ground level without any embankment. 1.5 m wide space for hedges shall be considered after earthen shoulder of 1.5 to 2m depending on land availability/ site conditions. Para 11.26.1 of IRC SP:21-2009 recommends that there shall be no plantation within 1.5m of the carriageway edge and curve sections shall be avoided and hence shall be obliged. In plain terrain as per para 26.1 of IRC: SP: 87-2013, IRC: SP-73: 2015 & IRC: SP: 84-2014 for 6-lane, 2-lane & 4-lane carriageway respectively earthen shoulder shall be of 2m width thus ensuring the safe distance. Safe stopping site distance of 180m and intermediate/ minimum desirable sight distance of 360 m corresponding to the designed speed of 100 km per hour shall be ensured on all curved sections, on the innermost lane of the curve for 2-lane/ 4-lane /6-lane roads as per above referred IRC codes.

Shrub species shall be selected based on the nature of plants, climatic condition, type of soil, availability of water, purpose and origin of species. A list of suggested species is given in **Table 1**. Choice of species shall however be referred from Plantation matrix developed by NHA based on its ranking.

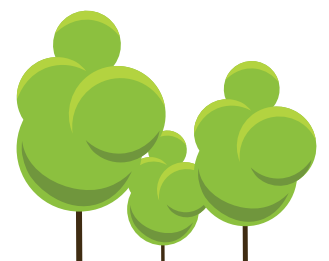
4.22 Maintenance

Apart from maintenance and monitoring recommendations made in IRC: SP: 21-2009 and Green Highways (Plantation, Transplantation, Beautification and Maintenance) Policy, 2015, additional maintenance activities as mentioned under point. 4.1.2 Shall be carried out.

4.3 PLANTATION AS A REPLACEMENT OF ANTI-GLARE SCREEN IN THE MEDIAN

4.3.1 Concept

It is already mentioned in various IRC codes that plantation in the median can act as anti-glare screen. Also it is already mentioned in IRC:SP:21-2009 and the Green Highways (Plantation, Transplantation, Beautification and Maintenance) Policy, 2015 that median with up to >3 m can have one row of shrub plantation and that with 5 m can have two rows of shrub plantation.



Considering the average height of head lights of cars and trucks it is suggested that hedges (continuous shall be preferred or space interval not more than 3 m) with minimum 1.5 to 2 m height in the median can act as anti-glare screen for opposite side moving vehicles. It is also mentioned in above referred code that in case the median width is less than 1.5 m, only grass turfing is Slowed However, with the right choice of species shrubs with foliage spread of < 1.5 m can be planted along medians. In case of paucity of space, it is suggested to construct concrete planters beneath the median space, erect a 'Y' shaped or straight bamboo fencing and plant climbers on both side of it measuring up to 2 m height only (Figure 15). This possibility should also be explored for flyovers passing through urban areas wherein the median width is one of the major constraining parameters. It may also be noted that use of shrubs in place of polymer based antiglare screen can reduce the carbon footprint of highways.

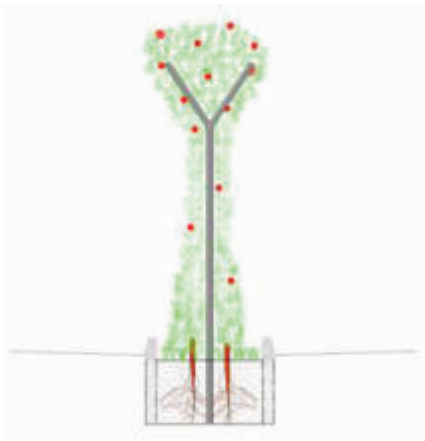


Figure 15: Climber on median Y-shaped bamboo railing to act as antiglare screen

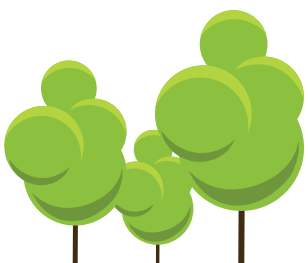


Figure 16: Caesalpinia planted along median acting as anti-glare screen; through proper pruning, can be maintained as effective anti-glare hedge

Climbers/ creepers' species shall be selected based on the nature of plants, climatic condition, type of soil, availability of water, purpose and origin of species. Use of non-browsable species like Caesalpinias (Figure 1&, Bcgainvilleas, tecoma etc will be effective. A list of suggested species is given in Table 1. Choice of species shall however be referred from Plantation matrix developed by NHGM, NHAH based on its ranking.

4.3.2 Maintenance




Apart from maintenance and monitoring recommendations made in IRC: SP: 21-2009 and Green Highways (Plantation, Transplantation, Beautification and Maintenance) Policy, 2015, the following additional maintenance will have to be done for hedges/ shrubs planted for safety purpose:

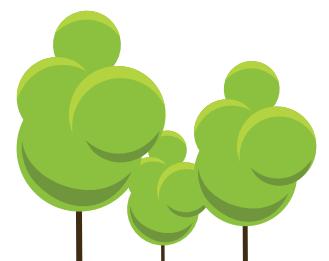








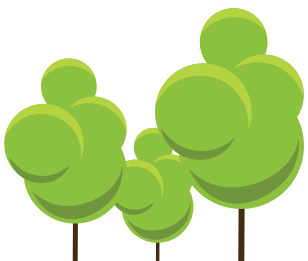
- Watering shall be through drip irrigation system especially in the median to avoid water & soil spillage on road, prevent damaging of pavement due to water seepage and also prevent wastage of water.
- Timely pruning is necessary to avoid branches falling on/ bending over the carriage way

Table 1-Suggested plant species





Common Name	Botanical Name	Photographs of Shrubs	Appearance	Description of Plants
Coastal/ Cotton wood Hibiscus	Hibiscus tiliaceus		Evergreen foliage & flowers	Hibiscus tiliaceus reaches a height of 4–10 Meter, with a trunk up to 15 cm in diameter. The flowers of H. tiliaceus are bright yellow with a deep red center upon opening. Over the course of the day, the flowers deepen to orange and finally red before they fall. The branches of the tree often curve over time. The leaves are heart shaped and deep red.
Hibiscus (Desi)	Hibiscus rosasinensis		Evergreen foliage & flowers	Hibiscus is a bushy, evergreen shrub/small tree that can grow up to 2.5-5 meter tall and 1.5–3 meter wide, with glossy leaves and solitary, brilliant red flowers in summer and autumn. The 5- petaled flowers are 10 cm in diameter, with prominent orange-tipped red anther. The stem is erect, green, cylindrical and branched. The leaf shape is ovate, the tip is acute and margin is serrated.
Cassia glauca	Cassia glauca		Evergreen foliage & flowers	This is a tall shrub or small tree up to 3 Mtr and produces long racemes of massed clusters of bright golden flowers, which appear on almost every branch, all of which are clad in attractive alternately arranged leaves, consisting of pairs of feathery, deep green ovate leaflets. Later appear the pea-like seed pods. It does best in a hot spot and full sun and well-drained soil.

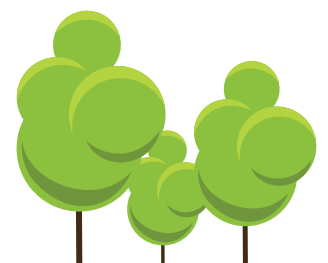







Common Name	Botanical Name	Photographs of Shrubs	Appearance	Description of Plants
Tecoma	Tecoma stans		Evergreen foliage & flowers	A large small or large, much-branched shrub usually growing 1.5 to 5 Meter tall. Stems are smooth, hairless and greenish in colour. The leaves are 10-25 cm long arranged in pairs and are borne on slender stalks 1-9 cm long. Flowers are bright yellow in colour, tubular in shape, and borne on short stalks that are somewhat curved or twisted. Flowering may occur throughout the year. Best for pots, beds, hedges and landscape.
Bougainvillea	Bougainvillea spp		Evergreen foliage & flowers	Bougainvillea is Perennial, Evergreen, vines, and shrub grows to 12 Meter. The leaves are green or variegated with yellow, cream, or pale pink, alternate, and egg-shaped, elliptic, or heartshaped. The mature branches are woody, brittle, and have slender spines at the leaf axils. Flowers are White to tinged yellowish or greenish. The farmore conspicuous floral bracts are pink, red, orange, yellow, purple, or white.
Cassia biflora	Cassia biflora		Evergreen foliage & flowers	A small shrub with cascading foliage, tiny leaves, and grows up to 3 meter. This early bloomer produces yellow flowers from fall to spring. This is drought tolerant. It appears the best if it is left to grow into an umbrella shape canopy.
Peacock Flower	Caesalpinia pulcherrima		Evergreen foliage & flowers	This shrub is also called Dwarf Poinciana due to the resemblance of its flowers and leaves to those of Gulmohar (Delonix regia). They are botanically related but Peacock flower plant grows only to a height of about 3 Meter, retains its leaves throughout the year, and blooms continuously. Flowers, which appear in clusters on long erect stems, are smaller than those of Gulmohar. The most common colour is red-orange, but one variety has pure yellow flowers.

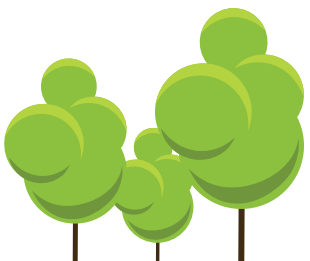







Common Name	Botanical Name	Photographs of Shrubs	Appearance	Description of Plants
Hamelia	<i>Hamelia patens</i>		Evergreen foliage & flowers	Hamelia is an ornamental, evergreen, small, fast growing, semi-woody, flowering shrub grows to 3 Meter and has red tinged, deeply veined leaves of about 10-20 cm length. It produces a showy mass of tubular, bright reddish-orange flowers. It also produces a showy fruit; the edible juicy berry turns from green to yellow, to red, and finally, black when ripe.
Chandni variegated	<i>Tabernaemontana coronaria</i> spp		Evergreen foliage & flowers	Chandni variegated is a spreading, bushy, manybranched, fragrant shrub with elliptic-oblong, wavy-margin. Grows up to 2.5 meter with thin, glossy, mid to dark variegated creamy leaves, paler underneath. Produces cymes of 4 to 6 waxy, pure white flowers. Scented at dusk and after dark. It bears white, waxy summer flowers and has oblong leaves with wavy margins that are dark green.
Chandni Single	<i>Tabernaemontana Coronaria</i> spp		Evergreen foliage & flowers	Chandni Single is a beautifully shaped evergreen, fragrant shrub have much branched shrub grows up to 2.5 Meter in height. Stems exude a milky latex when broken. The large shiny leaves are deep green. Flowers white fragrant, in axillary or terminal cymes Fruits follicles, ribbed and curved. The waxy blossoms are white five-petaled pinwheels that are borne in small clusters on the stem.
Dodonaea	<i>Dodonaea viscosa</i>		Evergreen foliage	Shrub or small tree 3-12 Meter. Bark reddish brown, flaking readily in irregular shards, flakes often detaching in masses toward trunk base; young branchlets flattened to triangular, glabrous. Young growth and buds sticky (viscid). Leaves green, yellow-green, bronze or red-purple. Flowers yellow-green to red-green.

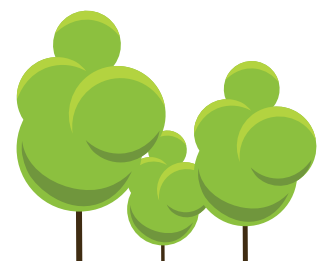





Common Name	Botanical Name	Photographs of Shrubs	Appearance	Description of Plants
Ficus panda	Ficus benjamina panda		Evergreen foliage	The Ficus Panda has evergreen lemon bright yellow light almost Round Thick leaves which small but broad, elliptic and leathery alternate up the stem. The trunk in beige in colour and surrounded by aerial roots. Heavy trunk with terrific aerial roots. Easily maintain desired shape & size.
Ficus benjamina	Ficus benjamina		Evergreen foliage	A broadleaf foliage evergreen small tree. It is widely grown as indoor houseplant, ornamental, hedge or topiary. Trunks are sometimes braided for ornamental interest. Glossy, pointed, oval to elliptic leaves. Twigs arch gracefully. Stems have milky sap. Easily maintain desired shape & size.
Murraya	Murraya paniculata		Evergreen foliage	Murraya is an ornamental, evergreen foliage, fast growing shrub grows up to 2.5 meter. The plant has a dense, twiggy habit and glossy, dark green foliage. It bears small, white, scented flowers.
Inermi	Clerodendrum inermis		Evergreen foliage	Inerme is a much branched, straggling/ climbing shrub, 2-8 meter tall. Terminal branches very often twine slender, twig, dark green. Leaves ovate to elliptical, 5-10 cm long, acute to acuminate tip, green, smooth, slightly shiny upper surface, margins entire, leaves opposite, simple joined with White flowers.
Golden Duranta	Duranta erecta		Evergreen foliage	Duranta golden is an ornamental, spreading, Flowering, hedge shrub. It can grow to 6 Meter. The leaves are light green, elliptic to ovate, opposite, and grow up to 7.5 cm long and 3.5 cm broad, with a 1.5 cm petiole. The flowers are lightblue or lavender, produced in tight clusters located on terminal and axillary stems, blooming almost all year long. The fruit is a small globose yellow or orange berry.





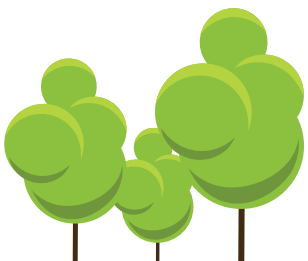
Common Name	Botanical Name	Photographs of Shrubs	Appearance	Description of Plants
Climbers and Creepers:				
Madhu-malti	Quisqualis indica		Foliage & Flowers	Madhumalti / Ragoon Creeper are fragrant creepers grows up to 70 feet. Clusters of fragrant white pendulous trumpets open white then change to pink, red and finally a deep maroon. A vigorous twining climber blooming profusely throughout summer This plant needs support for growing and is very useful in covering fences, supports, and walls. The fragrant white flowers grow in pendent racemes, quickly changing to pink then red, making a spectacular show. Best for houses & gardens.
Rakhi bel	Passiflora foetida		Foliage & flowers	Rakhi bel is a perennial climber with woody stem grows to 15-20 meter meter with tendrils seeking a support and produces beautiful white flowers with purple, blue, or pink calyx crown blooms. Flowers almost all the year round. The leaves are alternate, palmately five-lobed 10–18 cm long and wide. The flower is complex, about 10 cm diameter, with the five sepals and petals similar in appearance, whitish in colour, surmounted by a corona of blue or violet filaments, then five greenish-yellow stamens and three purple stigmas.
Rat ki rani	Cestrum nocturnum		Foliage & flowers	Rat ki rani is a fragrant, beautiful shrub. It has glossy, smooth, simple leaves 4"-8" long. Vine-like stems reach up to 12 feet in its native habitat. It blooms in cycles throughout warm weather. Greenish-creamy white tubular flowers rise from above leaves along the stem, followed by shiny white, fleshy berries. Although the flowers are not showy to the eye, their sweet scent can overpower. The perfume is distinctly powerful at night.



Common Name	Botanical Name	Photographs of Shrubs	Appearance	Description of Plants
Parda bel	Vernonia elaeagnifolia		Foliage & flowers	Parda bel is a creeper with slender stems climb up and then fall down beautifully over a wall or railing. The tender stems, all hanging down form a curtain. Basically it is a foliage plant, grown primarily for its habit of forming a green curtain. The species name elaeagnifolia means, having foliage resembling Elaeagnus or pure olive. Off white flowers appear in bunches.
Thunbergia	Thunbergia grandiflora		Foliage & flowers	Thunbergia is an evergreen creeper, grows to about 20 meter and have a long root system with a deep tap root. The stalked, opposite leaves, which have a rough surface, are quite variable in shape. They may be triangular or ovate and the margins may be toothed, lobed or entire. The blue to mauve flowers with long tube that is pale yellow inside.
Morning Glory	Ipomea violacea		Foliage & flowers	Ipomea is creeper with woody, twining and hairless stems growing to 5 meter, often longitudinally wrinkled. Leaves are circular or ovate, base deeply heart-shaped, with rounded lobes, and a sharp tip. Lateral veins are 7 or 8 pairs. Flowers occur either singly or in bunch of few. Flowers open at night, hence common name is Moonflower. Flowers are white, pink & blue.

4.4 PLANTATION FOR SAFETY OF HUMAN HEALTH, RESTORATIVE BEHAVIOUR & AVOID ROAD ACCIDENTS

Amongst many sources of air pollution, vehicular operation is also one. The main primary pollutants emitted by vehicles plying on the roads are SO_x, NO_x, CO, CO₂, PM₁₀ and HC. There are several steps being taken in terms of introduction of cleaner fuels, vehicular emission norms, Corporate Average Fuel Consumption standards that are





likely to bring down emission levels of pollutants but cannot eliminate them. The road users especially drivers are exposed to such pollutants for longer time.

Driving is a job of concentration and pollutants like NO_x causes irritability and diverts concentration from driving and thus may result into accidents. A study shows that increase in level of nitrogen dioxide (NO₂) by just one pg(rnz in the atmosphere leads to a rise in 2% of the number of vehicle collisions. It is argued in this study of London School of Economics that NO₂ causes irritation in eyes and nose of the drivers causing their loss of concentration and in turn accidents (Sager, 2016) (Figure 17).

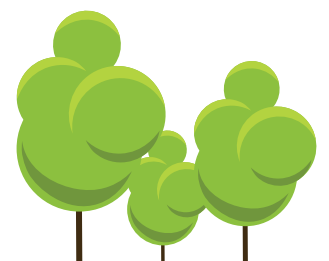
Plant species tolerant to at least the primary pollutants shall be planted along roads and highways. While there do exist pollution tolerant and resistant species, there are also plant species which act as sink for particular gaseous pollutants, and suspended particulates. Document titled 'Guidelines for Green Highways Policy' developed by NGHM, NHAI including plantation matrix shall be referred along with IRC:SP:21-2009 for selection of species.

Apart from acting as pollution sink, green vegetation cover along the road also has a restorative impact on the drivers/ users by reducing stress (Wolf, 2005; Egorov, Mudu, Braubach, & Martuzzi, 2016) increasing their tolerance level and thus can avoid aggressive driving and road rages (Marie & Nasar, 2003). Restoration is generally described as improved attention and recovery from stress and mental fatigue. Studies rely on objective measurements of physiology such as changes in blood pressure, heart rate, electro-dermal activity and electromyographic activity and various objective tests of cognitive performance.

Psychological theory suggests that other responses are associated with visual quality, such as affect cognition and behavior (Kaplan & Kaplan, 1989). Stress is a serious public health issue and commuting is one of the most stressful experiences. Increased blood pressure is associated with longer and more difficult commutes. Lowered satisfaction, higher illness rates, absenteeism and lower performance on various cognitive tasks are all conditions found to be related to longer or more difficult commutes (Novaco & Milanese, 1990). Road side landscape views can mitigate stress response (Ulrich, et al., 1991).

Green color of vegetation is soothing for eyes and helps to calm down mind and behavior. The spectral sensitivity of green is high on a wider range of frequencies. Hence, it easily stimulates a larger number of light cones (Medium wavelength) of human eyes as compared to pure red (Long wavelength). Since the activation of Green stimulates a larger percentage of cones, it is found soothing or pleasant to look at. This also supports the finding mentioned in previous paragraph that vegetation has a restorative impact on human behavior.

Trees also have the ability to reduce heat islands effects by providing shade, leading to lower pavement temperatures (Dixon, K, Wolf, & Seattle, 2007). Presence of green tunnel (tree cover on both side of road with canopy spreading over the road at a considerable height that looks like tunnel) also creates a cooler environment to drive. There is a high positive correlation between mental irritation and rise in ambient temperature and thus lowering of temperature due to shady trees can have positive impact on driver's behavior. Green tunnel (Figure 18) is good however for narrower roads with low traffic volume (Ree, Smith, & Grilo, 2015). A study conducted, taking



in everything from archaeological data to historical studies, and stretched from 10,000 BC to the present day found a relationship that as the world got hotter, people fought more. "For each 1 standard deviation change in climate toward warmer temperatures or more extreme rainfall," the researchers wrote, "median estimates indicate that the frequency of interpersonal violence rises 4 percent and the frequency of intergroup conflict rises 14 percent." (Hsiang, Bruke, & Miguel, 2013) This study again supports the fact that aggressiveness in driver's behavior can be reduced to certain extent due to the effect of shady trees and formation of green tunnel.



Figure 17: Relationship between air pollution and road accidents

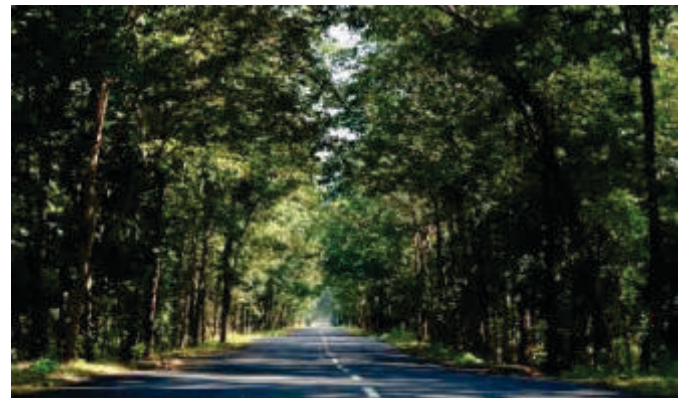


Figure 18: Green Tunnel

4.4 PLANTATION FOR SAFETY OF HUMAN HEALTH, RESTORATIVE BEHAVIOUR & AVOID ROAD ACCIDENTS

Road side vegetation provides shade and helps reduce the road surface temperature that in turn can reduce the heat island effect in urban areas (Cha & Lim, 2011). As per Environment Protection Agency shaded surfaces, can be 11–25°C cooler than the peak temperatures of unshaded materials (Heat Island: United Nations Environment Protection Agency, 2018). Apart from having a restoration impact on drivers' behavior, reduced pavement surface temperature due to vegetation can also reduce accidents. Often vehicle tyres burst due to over speeding, increased temperature and friction with concrete pavement surface leading to accidents. For instance, the bare and wider look of Yamuna expressway (Figure 19) leads to over speeding of vehicles that has been the main reason of around 700 accidents out of 2905 accidents in four years. Out of 700 around 320 accidents were due to tyre burst (TOI, 2016). Amongst other ways like maintaining tyre conditions etc; developing green tunnel/ corridor is one way to reduce such accidents. Firstly, it will reduce the road surface temperature (Cha & Lim, 2011) (Heat Island: United Nations Environment Protection Agency, 2018) and secondly, the existence of green corridor will give a sense of road narrowing down that will psychologically affect the drivers to slow down the vehicles (Calvi, 2015) (Naderi, Kweon, & Maghelal, 2006).

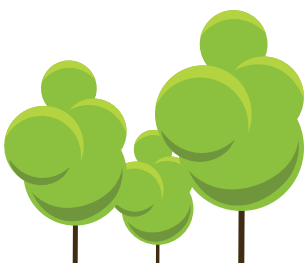




Figure 19. Bare and wider look of Yamuna Expressway

(Is there any study on the longevity of the CC roads under vegetation cover versus denuded roads?)

4.6 PLANTATION AS A TOOL FOR SLOPE PROTECTION

The fact that plantation can be used for slope protection that in turn can prevent land slide and is an important factor of safety has been already dealt in detail in IRC:56-2011 & IRC:SP:106-2015. Bioengineering techniques and hydro seeding (Figure 20) shall be adopted based on the type of cut slope surface.

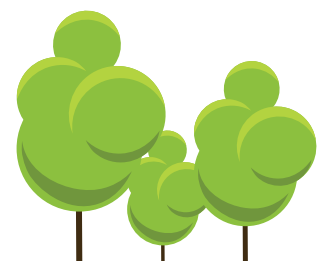


Figure 20. Hydro seeding used for slope stabilization

5. INSTITUTIONAL ARRANGEMENT FOR CARRYING OUT MAINTENANCE

Plantation Manager shall be appointed in each PIU and made in-charge of maintenance of the plantation zones reporting to Project Director. This shall be followed for Public Private Partnership (PPP), annuity based as well as Engineering, Procurement and Construction (EPC) driven projects.

In the case of Public Private Partnership (PPP) driven projects, Plantation Manager shall be engaged in each Project Implementation Units (PIU) and made in-charge of maintenance of the plantation zones reporting to



Project Director. In the case of either the as well, it is essential to follow the mechanism of having Plantation Manager in place. ??

Under the Plantation Manager, there shall function a group of plantation agencies which will engage garden staff (on contract basis) from the villages/ towns along the project road section. Each road shall be divided into several stretches of 20 kms or as deemed feasible and person hired for the adjacent village to a particular stretch shall be made responsible for maintenance of plantation in that stretch. Special training programs shall be designed for these gardeners by the plantation officers to take care of the plantation safety barriers. Contract renewal shall be performance based. Further to encourage efficient work, awards and monetary incentives shall be given annually to the best performing garden staff within a PIU annually. This approach will lead to greater community participation, generation of sense of responsibility and ownership, employment generation, and better maintenance of the road stretches. Their contract period of one year shall be extended based on effective performance and requirement. Figure 21 gives a flow chart of the institutional arrangement.

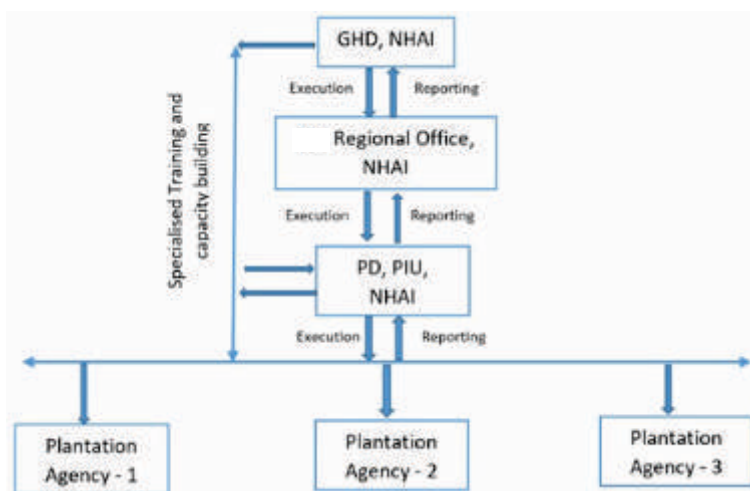
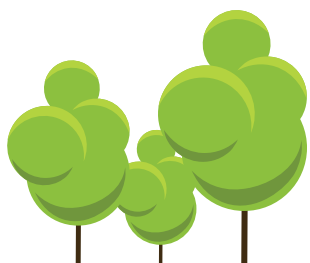


Figure 21 Institutional Arrangement for maintenance work of plantation safety barriers

6. CONCLUSION

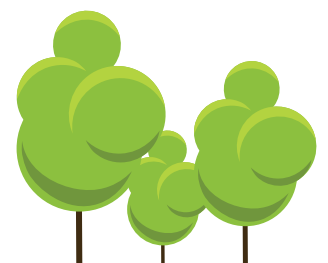
The above measures are indicative and it is further required to establish their technological feasibility on project to project basis before implementing. It is however, recommended through this document to establish the technological feasibility of the above mentioned measures on project basis and include the findings along with the Plantation Plan that is recommended to be included in every EIA (as part of DPR) as per NHAI OM No. 1.1.24/2017 dated 18.12.2017 regarding policy guidelines for Green Highways Projects. It is also suggested that this document shall be considered by the relevant committees of IRC to incorporate such measures into relevant codes to ensure a safer road with community and environmental values. It is further recommended to conduct analytical studies to establish the exact statistics on accidents due to trees, role of trees in leading to accidents and role of trees in preventing additional loss of damage and properties.





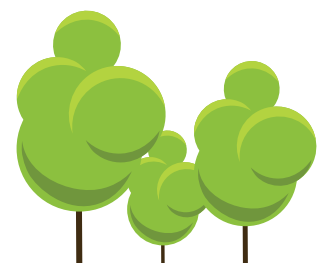
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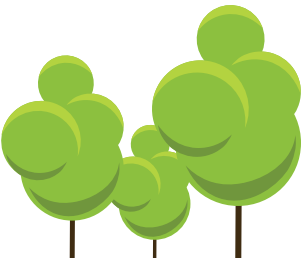
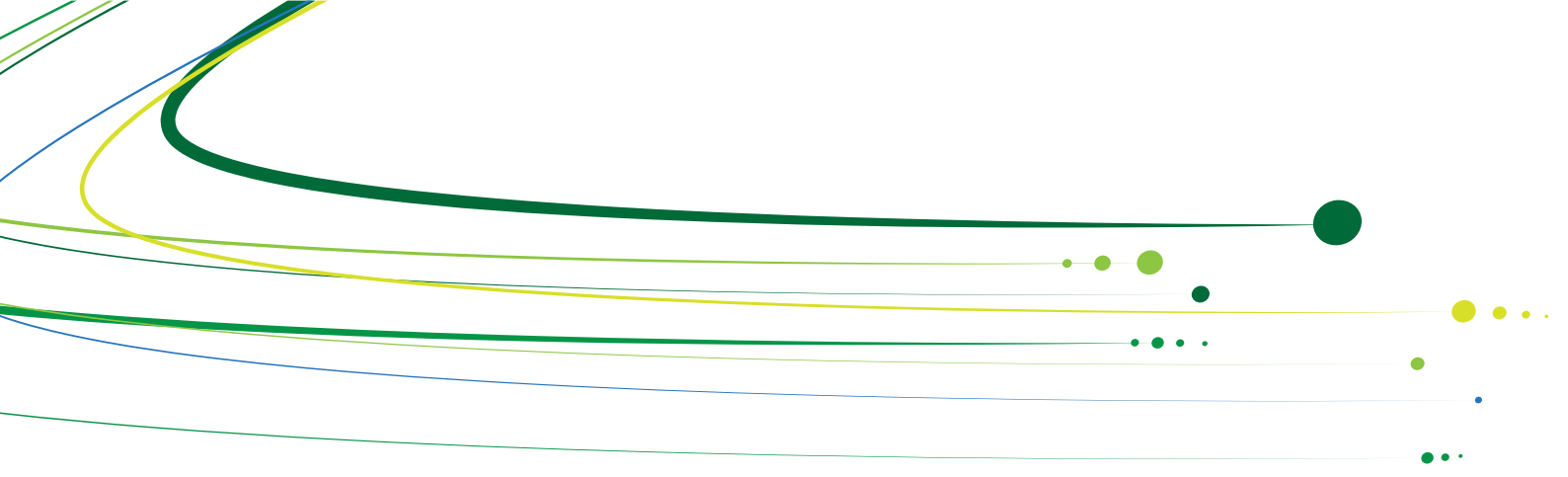
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