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Feasibility of Using Hybrid Anti-Death Guardrails and Sound Barrier System to Increase Safety and to Reduce Sound Pollution in Highways

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Abstract: **One of the key issues in road and urban transportation to all managers, experts, and governments is "SAFETY". Safety is directly associated with lives, health and properties of each country citizens. Every year great number of events related to deviated vehicles happen in roads and urban areas which cause people maims and death. Thus using guardrails will be effective to prevent vehicles from deviating roads, increasing aboard and pedestrian safety in the surrounding environment of path. It's obvious that types of guardrails being used are very effective on reducing the damage severity. The relation between safety and sound pollution reduction is an interesting issue in various fields. Using an intelligent protection system at highway margins could be studied as a safeguard for deviated vehicles and also acting as a sound barrier. This hybrid system can reduce costs and damages to the sound barriers (observed in the crash tests) and also decrease the space being occupied. Sound pollution is a serious problem in modern machine societies and lack of attention to it might lead to more direct and indirect costs which finally return to the society. So this article attempts to study the "hybrid anti-death guardrails and sound barrier system" in order to reduce sound pollution and providing safety on and around highways in urban communities.**

Keywords: **Anti-Death Guardrails, Highways, Reduce Sound Pollution, Safety, Sound Barriers, Vehicles.**

1. INTRODUCTION

Safety guardrails are the most common security systems in roads. The role of these guardrails is absorbing and eradicating the deviated vehicles' dynamic energy and returning vehicles into their safe path and preventing them from being thrown in to valley. The common safety guardrails are merge and median guardrails that the merge one is based on relative strength and divided into three groups:

1-flexible, 2- semi-rigid, 3-rigid. This article has been investigated flexible merge guardrails at the time of strike to vehicles. Flexible guardrails also include: three cables guardrail, two waves targe with flag base system and 3 waves targe with flag base and usage of them have some qualification in different places. It should be noted that the present application is used in highways and two related issues are important to note:

a. Control the vehicles with high speed to provide safety and preventing them from deviation.

b. Creating sound barriers to reduce sound pollution for the residents near highways.

2. FLEXIBLE GUARDRAILS

Flexible guardrails act like an arc of drainage and their tasks is returning the deviated vehicle into the main path. These guardrails have the most displacement, deflection and energy absorbing among other kinds of guardrails and due to such deformation minimum decrement in acceleration will happen to the car and it's passengers during collision. As the beginning and end of this kind of guardrail is sharp, this part should be covered and made safe. One of the solutions is using cable guardrails. Since 1992 ten thousand kilometers of cable guardrail has been installed and used in America, Africa, Asia, Europe and Oceania. Human casualties and financial losses have been reduced by using this guardrail.

Since 1385 usage of cable guardrails has been proposed in transportation administration in Iran. These kinds of guardrails are made up of "I" like or chute type base and three or four cables placed in main thread of base and the end checkrein of these guardrails stay on concrete foundation [1].

The other way to stop guardrail infiltration into vehicles as they impact to start or end of them is to pinch the beginning of guardrail, bend it down and dig it in the ground. It's important to know that use of these guardrails have some constraints, typically it's not recommended to use them in arcuate route with small radius. Therefore in the following text, the anti-death guardrails as a kind of flexible guardrail are assessed.

Figure 1: Example of cable guardrail

3. ANTI –DEATH GUARDRAILS

One kind of intelligent safety guardrail is anti-death, which has been made from composite profiles system that could reduce the severity of crashes by using stopper systems in order to prevent the diversion of vehicles. This kind of guardrail has more flexibility and strength than the

other existing guardrails. For this reason this system has more safety and could reduce the percent of occupant's death. It's important to mention that this system has no limitation in installation.

Fender properties, strength, perfect flexible base, stopper system used to prevent vehicles from deviating, grating spacing sizes to reduce crash severity have been used instead of using a vertical base that causes more flexibility as vehicles crash to them.

Another advantage of this system is having the capability to install sagacious digital speed meter and could be installed on common metal guardrails.

4. Sound Pollution and the Role of Sound Barriers on Reducing it

Nowadays the capacity of highways has been developed during the construction of new highways and also number of vehicles grows. Sound pollution creates serious problems with some factors such as vehicles transportation in peak times for nearby highways residents. The physical and psychological effects of this pollution are very high especially on humans in urban environments so some technical and international standards have been set which all the governments and urban custodians should observed them. In some cities like Tehran the amount of pollution is above this limit and according to various technical investigations, some of the points are in the critical and dangerous situation. Currently and in the past, the most important thing that all the experts have noted has been the lack of comprehensive strategy in different technical and management levels.

The necessity of extensive highway network which is appropriate for new transportation systems can be fast and safe and are the most important infrastructure factors for developing every city. From the time human began using vehicles, developing countries that made vehicles used this human achievement for safety, so they have done extensive researches for safety and improving usage of highways. Today the efforts of those years are safe highways. Unfortunately in our country no efforts have been done to make vehicles usage safe. High rate of increment in environmental pollutants and crashes and criminal damage have been introduced the necessity of highway safety. Sound pollution is determined with the amount of traffic zone. Installation of sound barrier in highways or creating a large green space in the margins of streets or houses can reduce up to 15 db (75%) of sound pollution. Greens on the sidelines of a small hill in marginal crowded highways are the effective method and it is the common action in urban architecture design of our traffic [2]. The other effective method that reduces sound pollution is using of sound barriers. Before and after implementation of these walls, the model of sound pollution can be distributed by applications which have the capability to model air pollution control strategies. Sound barriers are the structures that decrease the amount of sounds between sound barrier and the sound source.

During design of sound barriers several factors should be considered such as shape, material, height, length and emplacement and also for considering this, the necessity of especial expertise is obvious.

Due to the volume of produced sound in source, determination of the wall location, material, length, height can be done. By considering the standard values, we could obtain maximum decrement in sound level. However these barriers occupy some space around the highways and in places where there is a lack of space, installation of sound barriers becomes a problem. These walls can be made of plaster, wood, cement, concrete, mortar, metal and so on. Many efforts have been done to have perfect and beautiful acoustic barriers, these barriers should reduce at least 5 db of equivalent pollution level and such approval is required for sound barriers. In designing sound barriers the costs of adverse effects on environment, proper lighting and compatibility with the surrounding space should be considered. Selecting such walls will be according to local conditions. Some factors in choosing the type of sound barriers are, distances between the sound receiver and highways, volume of passing traffic and the importance of traffic disruption. Sound barriers are divided into the following types by considering appearance, construction shape and some tasks which must be considered for them [3].

- Barriers that columns and parts were prefabricated and parts are sheathed in track column.
- Composite system (panels) made with the column and separated parts.
- Composite system (panels) made with the parts and continuous columns.
- Zigzag-shaped barriers
- step fences
- Prefabricated panels and bases mounted on the guardrails and prefabricated fences having a slope on one side.
- Prefabricated fences that parts (panels) and columns in them are connected and continuous.
- Composite system (panels) made with the parts and continuous column.
- Built in place fences, parts (panels) and base made at the location.
- Hill-shaped fences

Also these barriers could be made from prefabricated concrete and sound barrier arable concrete. Concrete is resistant in contrast, high temperatures, intense sunlight, moisture frost. Another type of sound barrier is transparent barrier that the plastics and glasses materials in it could be colored or turbaned.

In recent years the important issues are constructional costs and sound barrier tests that they are very high. For this purpose some arrangements were taken to maintain these barriers. Also the strength and material of these barriers are high but due to intensive crashes and vehicles and high speed, damaged may result during the utilization and accident tests.

Different materials used for construction of sound barri-

ers are presented in Table 1:

Table 1: Different materials for constructing sound barriers

Material	Thickness	Mass per unit area	Reduced sound
polycarbonate	8-12	10-12	30-33
Acrylic	15	18	32
Dence concrete	100	244	40
Clay bricks	150	288	40
Steel	1.27	9.8	25
Aluminum sheets	1.59	4.4	23
Wood	25	18	21
Composite boards	25	16.1	23

5. Combination of Anti-Death Guardrails and Sound Barriers for Improving Safety and Reducing Sound Pollution in Highways

As mentioned in the previous section due to the high cost of building these barriers, we should avoid vehicles to crash with them. None reinforced concrete barrier could be a good obstacle between vehicles and walls. Recruiting the best and practical barriers are anti-death guardrails which in addition to reducing drivers and vehicles damages also could be a good base for sound barrier installation.

As mentioned some of sound barriers occupy relatively large space in the margin of highways and this issue has become a problem in places where there is a problem of space shortage. Considering the variety of sound barriers, there is a possibility of combining guardrails and barriers for safety and reducing pollution. Installation of these barriers on guardrails also could help to reduce space occupied with them and the visual beauty of surrounding highways.

Also according to that sound barriers should be placed at appropriate heights, installing them on guardrails could create adaptable height. In crash tests the main point is that, when the barriers placed on guardrails, the vehicles will impact to them not sound barriers. So the crash tests could be done only for guardrails and as vehicle crash to guardrail the strength will be tested for keeping these barriers on guardrails. Perhaps some costs will be spent for increasing guardrails and sound barriers strength but the slight increase in costs might be negligible against the advantages.

Sagacious speed meter on guardrails could report the speeds, intensities and crashes. The height of barriers is about 4.5 meter and as they are implemented in long length they could have effective influence in decreasing pollution. For reducing the sound pollution to the minimum, sound barriers should be high enough to prevent the direct route between receivers and source. If the sound barrier is short or has some spaces among its parts, the sound could pass over the walls and as a result the efficiency will be decreased. Acoustic barriers should be a minimum height of 0.1 highways width. (Distance between the two sides of barriers in highways). For example if the highway width is 30 meter, the minimum height should be 3 meters [4].

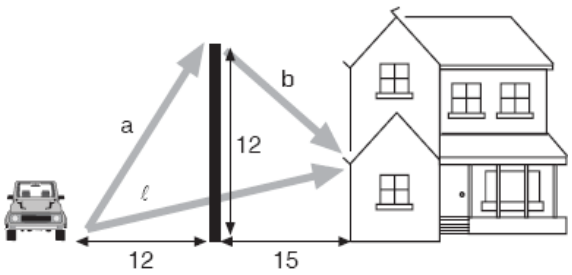

Figure 2: The example of longitude scheme of the route as the sound barrier has been installed

Figures 3: Examples of sound barriers

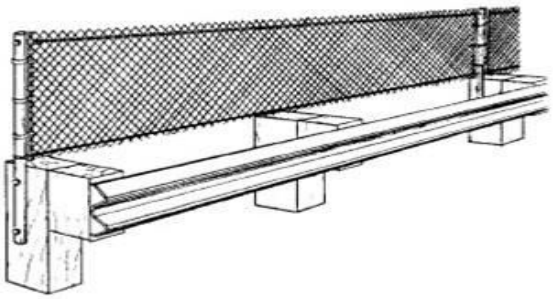

Figure 4: The fence on guardrail

6. Some Tests on Sound Barriers and Guardrails

- One of the tests that had done on guardrails under real conditions is a crash test. In these tests the artificial or dead dummy is used with the impact sensors to estimate the impact intensity and finally determining it for actual conditions. Crash test has been also used in sound barriers but their costs are very high.
- Another test is crash with computer simulations. Computer science and electronics have enabled progress to help researchers simulate the vehicles and flexible guardrails crashed in place by the result of experiments. Achieved the required results, models have been proposed for other forms of accident (like; type of speeds, variety crash angle, guardrails with different rigid levels). Usually the output patterns are like the MADYMO pattern (it indicated impact intensity) [2].
- Other test is based on numerical simulations. Since the impact tests are very costly and the number of sample tests are commonly limited and always may not provide the best quality tests, so the numerical simulation that are efficient and real can also provide perfect and useful results.

Finite element modeling used the ANSYS software and for analyzing impact using the LS-DYNA in numerical simulations.

One of the powerful resolvers that are currently used for the complex dynamic phenomena simulation is LS-DYNA. In addition this resolver in dynamic analysis is able to solve various problems in different areas of physics including solid mechanics, heat transfer, fluid dynamics and traffic. Currently this software has been progressed with LSTC.

Numerical simulations using nonlinear finite element has been effective tools in design and calculating this system [5]. The main purpose of this article is in urban areas and highway safety and maximum limited speed in these places is 100 km/hr, required performance levels are proposed in table 2[4].

Table 2: Required performance level

Level	Vehicles	Design speed/(km.h^{-1})	Impact angle /(^{0})
Low	0.8 t small car	70	20
	0.2 t utility	70	25
Regular	0.8 t small car	100	20
	0.2 t utility	100	25
	0.8 t truck	80	15

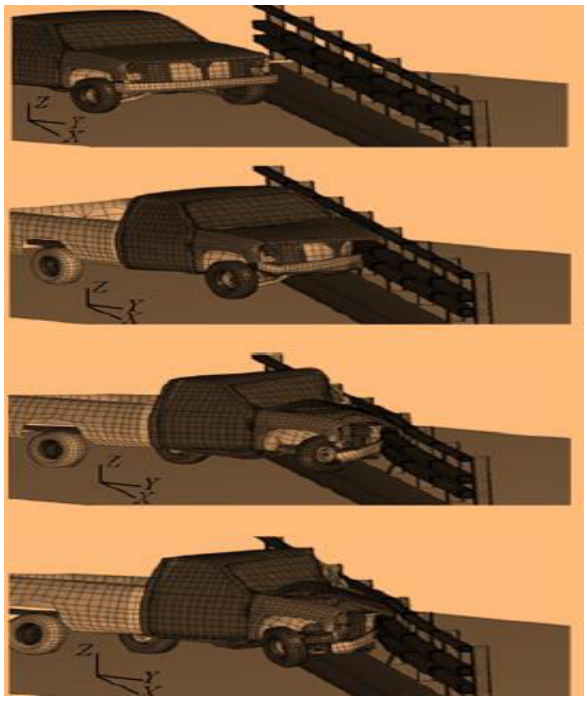

Figure 4: Images of the simulated utility collision in to guardrail with 100 km/hr speed and 25degree impact angles

The results of this test indicate that in collision among vehicles and anti-death guardrails, the front side of vehicle in impact with guardrail goes into it and finally returns into the ordinary state [6].

7. Reducing Sound Effects by Kurt and Anderson Formula

Reducing sound effect with installing barrier has been calculated by Kurt and Anderson suggested formula [7]:

$$N = \frac{(a + b - l)f}{C0}$$

N: fernosel number as a dimension less number that indicated how long wave motion will be taken with this barrier and has been calculated with figure 5

l: direct distances between resource and receiver

a, b : the length of two parts of new path as a result of barrier

f : sound frequency

C0: wave motion speed in air :100 ft/s

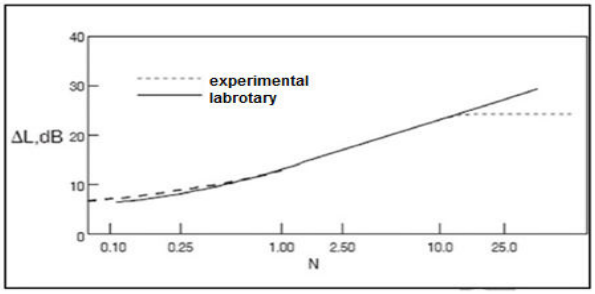

Figure 5: indicates reducing sound effect rate with fernesel number for experimental and experienced dates

7. SUMMARY AND CONCLUSIONS

Due to heavy economic and social damage in crashes and sound pollution, all the researches have been emphasized that it is necessary to design, create, edit and install types of equipment related to these cases in urban roads. This necessity in developing countries especially Iran will be felt more because the traffic safety indicators are very low and sound pollution is very high. Using the new generation of guardrails designed as anti- death guardrails will increase the user's safety in routes with heavy traffic. Also the combination of these guardrails with sound barriers has more effect to prevent vehicles impact to sound barrier and occupy less space. Investigating, developing, describing and doing different experimental tests about this issue causes to give an innovative learning model in safety and sound pollution.

At the end we emphasized that sound pollution is a serious problem that disregarding it will make the situation worse and impose to have side and direct costs which further leads eventually returns to society.

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