Effectiveness of Speed Humps Ranged at Different Intervals Considering Roadside Environment Including Vehicle Speed, Noise and Vibration

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Abstract: This study aimed at finding appropriate interval of ranged speed hump from the viewpoint of noise and vibration as well as effect of speed reduction through two experimental installation. In the experiment, "sinusoidal mobile humps" were used. In the first experiment, conducted in Kokubunji city, it was found that 60m-inerval can reduce speed less than 30km/h in all over the road section. However, residents complained the noise caused by re-acceleration. In the second experiment conducted in Bunkyo-ward, Tokyo, the intervals between humps reduced to 20m to make drivers to "give up" to re-accelerate. Judging from the result of questionnaire survey and noise observation, it was successful.

Key Words: Traffic calming, Traffic safety, Speed hump, Noise

1. INTRODUCTION

Speed humps are quite widely prevalent almost all over the world except for Japan where people are very nervous about noise and vibration caused by traffic on speed humps. Even in countries where speed humps are popular, the noise and vibration have become serious issues (Harris et al., 1999; Lahrmann et al., 1992). From 1990 several researches to reduce noise and vibration of speed humps were conducted to find "sinusoidal" shape is the best from the viewpoint of noise and vibration as well as passenger's comfort (Sayer et al., 1999).

In 2000, the authors have developed "sinusoidal mobile hump(FLEXITEC)" with Nippon liner Co., Ltd. made of rubber. It is "mobile" because it consists of 1m square units. So far, the authors have proven that FLEXITEC can "reduce" noise of the site because it can reduce...
speed reducing noise of engine while it makes little noise due to the sinusoidal shape and rubber material. It has been already proven that FLEXITEC installed in front of the non-signal intersection can dramatically reduce traffic accidents by waking drivers.

The next target is installing speed humps in the road section where drivers drive exceeding speed limit of, say, 30km/h. To make drivers to keep lower speed than speed limit over the road section, single hump will not be enough because drivers will raise speed again after passing through the hump.

In this paper, the authors try to find the appropriate intervals of installing speed humps in road section to keep the road calmed. By using FLEXITEC, it is easy to conduct this research because speed humps can be installed experimentally and temporarily.

2.  **EFFECT OF SPEED HUMPS RANGE AT 30, 40, 60, AND 100 METER INTERVALS**

2.1. **Description of Social Experiment Conducted in Kokubunji City**

This part explains a social experiment with four ranged speed humps at four different intervals; 30m, 40m, 60m, and 100m. The social experiment was implemented along the Kokubunji Koko Higashi Dori Street running north-south in Kokubunji city, Tokyo, Japan.
(Figure 4). It is a 3.6-meter wide and 600-meter long one way street; the direction of the one-way regulation is southward. Congested arterial roads run parallel to the subject street, and significant traffic pass through the street in the mornings and evenings on weekdays to avoid congestion along the arterial roads. During peak hours, as many as 500 cars per hour use the street as an alternate route. Most of these cars run at speeds over the legal limit of 20 km per hour. Thus, pedestrians and cyclists using the street are exposed to the dangerous situation and the residents living along the street suffer from the noise and vibration brought about by through traffic.

In order to solve those traffic problems, speed humps were experimentally installed on the street. The experimental period was for 4 weeks during October and November in 2006. Four speed humps were successively placed and the intervals between the humps were changed every 1 week: 30m, 40m, 60m, and 100m. The hump that was located at the north end was fixed throughout the experiment and other three humps were moved.

Before conducting the social experiment, there was a worry that drivers who do not know about speed humps run through the humps at high speeds and make loud noises. To avoid such situation, two kinds of humps, trapezoidal and sine curved humps, were used. Trapezoidal humps have comparably less impacts on motor vehicle occupants and make less noise than sine curved humps. One trapezoidal hump was put on the north end and three sine curbed humps were placed next to the trapezoidal hump. It was intended that drivers who experienced speed humps for the first time could learn the role of humps by the trapezoidal hump at first.

We conducted traffic surveys during the experiment and resident attitude survey after the experiment to evaluate ranged speed humps at four different intervals. In the traffic surveys, we measured vehicle speed, noise, and vibration during morning peak hours. In the attitude survey, we investigated how residents like the humps and how they thought about noise and vibration during the experiment. The following sections describe the results of the surveys.

2.2. Results of Traffic Surveys
2.2.1. Vehicle Speed
As mentioned above, in the four-week experiment, the intervals of four humps were changed
every week. We measured traffic speed at each interval, and before and after the experiment: we measured 150 vehicles for each situation. Targets were vehicles that traveling at free flow speed: it means that we choose vehicles not in congestions and not influenced other cars, cyclists, and pedestrians. Figure 5 shows block speed of vehicles from the trapezoidal hump located at the north end to the next hump. It displays the average, 85 percentile, the maximum, and the minimum speed for each interval, and before and after experiment. Before and after the experiment, the average vehicle speed is around 40km/h. All the average speeds measured in the experiment period are significantly slower than the average speed measured after the experiment at the 5% level. It suggests that the installation of ranged humps is effective at all the four intervals. However, the graph also indicates that the speed down effect decreases as the intervals become longer.

Figure 5 shows block speed of vehicles from the trapezoidal hump located at the north end to the next hump. It displays the average, 85 percentile, the maximum, and the minimum speed for each interval, and before and after experiment. Before and after the experiment, the average vehicle speed is around 40km/h. All the average speeds measured in the experiment period are significantly slower than the average speed measured after the experiment at the 5% level. It suggests that the installation of ranged humps is effective at all the four intervals. However, the graph also indicates that the speed down effect decreases as the intervals become longer.

Figure 6 shows typical speed trajectories measured in the experiment at the four intervals, and before the experiment. One sees that the vehicle speed become around 15km/h to 20km/h near or on the speed humps at all the four intervals. However, the longer the intervals become, the higher the vehicle speed between humps become. Regarding the interval of 100m, the vehicle speed between humps is almost same as the speed measured before the experiment. This result suggests that the speed down effect of ranged humps decrease as the interval of humps
become long.

2.2.2. Noise
We measured noise produced by passing vehicles. The observation points are installation positions of humps and middle points of each hump. Figure 7 shows average momentary value of noise measured when cars run through each observation points. Comparing the average value of the subject street, 72.7dB, the noise at the locations of humps and middle points of each hump is lower. At the middle points, comparably high value of noise was observed than at the installation points of humps. Reacceleration of vehicles after passing humps may influence the result. There is no significant difference in nose values depending on the interval of ranged humps.

![Figure 7 Average momentary value of noise at different intervals](image)

2.2.3. Vibration
We observed vibration generated by cars at the same points where noise was measured. Figure 8 displays average momentary value of vibration measured when cars run through each observation points. Contrary to noise, the value of vibration is higher at the middle points of each hump than at the locations of humps. The value of vibration observed at the midway between humps is higher than the average value on the subject road measured after the

![Figure 8 Average momentary value of vibration at different intervals](image)
experiment. However, the value of vibration does not exceed the environmental limit in Japan. So it is thought that the vibration generated during the experiment period does not influence the neighborhood. There is no significant difference in vibration values depending on the interval of ranged humps as in the case of noise.

2.3. Result of Attitude Survey to Residents
2.3.1. Description of resident attitude survey
An attitude survey was conducted to understand residents’ attitude toward the hump after finishing the social experiment. The survey method uses a questionnaire, and the targets were heads of households in the area shown in Figure 9. This is an area in the community where residents were taking the initiative in conducting the social experiments. The questionnaire was distributed by having it dropped into each mailbox by laboratory students, and it was collected by mail using a postage free envelope. After the time limit of the collection, a follow-up survey was conducted for the heads of households who did not reply. We distributed 353 questionnaires and got 179 responses: the response rate was 50.7%.

2.3.2. Attitude of residents living in the neighborhood
Figure 10 shows answer to the question whether you think the number of vehicles that slow down short of the humps increased because of the installation of humps. Out of all the respondents, 73.0% people answered the number “increased” or “somewhat increased”. The result indicates that many people knew as much about the slow down effect of the speed hump.

Figure 11 displays answer to the question whether you think traffic safety in the subject road changed during the experiment period because of the installation of hump. Regarding the question, the respondents were asked to reply to it from the stand point of pedestrian, cyclist, car driver, and motorbike rider. As a pedestrian and car driver, over a half of the respondents answered “safety was improved” or “safety was somewhat improved”: 56.5% of the respondents answered so as a pedestrian and 50.0% as a car driver. On the other hand, the rate of respondents who answered “safety was improved” or “safety was somewhat improved” for cyclists is 37.5%: the rate is comparably lower than the former two modes. One reason of the result may be that the gaps between the fences along the road and a hump were thought to be too narrow for cyclists. Furthermore, cyclists may have thought going by an oncoming car on
the humps, which is narrower than the road width, was not safe. These concerns would be solve when humps are installed permanently because the width of a hump can be modified for the subject road under the situation.

Figure 12 shows the answer to the question how you like installing humps on the road. To this question, 64.6% of the respondents answered “good” or “somewhat good”. Over a half of respondents showed a positive response about installing humps.
2.3.3. Attitude of residents living along the subject road

As mentioned above, the subject road is narrow and surrounded by residential houses. So the humps were placed near the houses. This suggests that the impact on residential environment was significant for residents living along the subject road. So we analyzed responses only from the residents whose house is along the road. The sample size is 18 respondents.

Figure 13 shows answer to the question whether you think the number of vehicles that slow down short of the humps increased because of the installation of humps. Out of all the respondents, 88.9% people answered the number “increased” or “somewhat increased”. The rate is higher than that of whole respondents. It is supposed that people living the roadside had more chances to see the experiment and the slow down effect.

On the other hand, the number of residents who thought noise and vibration became big during the experiment is large among the residents living along the road: 44.4% of them answered the noise increased during the experiment, and 50.0% of them answered that the vibration increased during the experiment.

Figure 14 shows the roadside residents’ answer to the question how you like installing humps on the road. To this question, only 27.8% of the respondents answered “good” or “somewhat good”. The value is significantly lower than that of the whole respondents. This result and the
former results indicate that although the residents living along the subject road highly evaluate the ability of humps to make the road safe, they are anxious about noise and vibration problems and had a negative impression of the installation of the humps.

2.4. Summary of the Experiment and Challenges
It is a big contradiction that residents along the road where humps were installed complained about problem of noise whereas observed noise level is low enough. Judging from free comments in questionnaire survey, the cause seems "re-acceleration" after passing the humps. By analyzing the result of this experiment, we have formulated a hypothesis about the reason of "re-acceleration" that intervals of humps are too long and they promote drivers to re-accelerate as a result.

3. EFFECTIVENESS OF HUMPS RANGED AT 20m

3.1. Description of Social Experiment in Bukyo-ward
Based on the lessons from the social experiment in Kokubunji city, we conducted another experiment in 2009. This time the interval of the humps are set at 20m. It is expected that the 20m interval keeps drivers not to reaccelerate their vehicles. The experiment was implemented in Bunkyo-ward in Tokyo, Japan.

The subject road is the ward road No.839, which is 4.5m width, 300m long one-way road. The direction of the one-way regulation is southeast. Traffic volume in the peak hour is not so heavy: it is around 40 vehicles per hour. However, the road runs through a residential area and there is an elementary school south end of the road, so a high level of traffic safety is expected. On the road, 4 humps were placed as a social experiment. In this experiment we intended to place 4 speed humps ranged at 20m, but considering the road condition, in reality, humps were ranged as Figure 15 shows.
We conducted traffic surveys during the experiment and resident attitude survey after the experiment to evaluate speed humps ranged at about 20m. In the traffic surveys, we measured vehicle speed, noise, and vibration. In the attitude survey, we investigated how residents like the humps and how they thought about noise and vibration during the experiment. The following sections describe the results of the surveys.

3.2. Results of Traffic Survey

3.2.1. Vehicle Speed
We measured momentary speed of vehicles at location of humps. Table 1 shows the average, 85 percentile, the maximum speed measured during the experiment and before the experiment. In all the categories, it is found that vehicle speed decrease during the experiment.

Table. 1 Momentary Speed of vehicles before and during experiment

<table>
<thead>
<tr>
<th>(km/h)</th>
<th>Before experiment (n=99)</th>
<th>during experiment (n=126)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>22</td>
<td>14</td>
</tr>
<tr>
<td>Max</td>
<td>40</td>
<td>27</td>
</tr>
<tr>
<td>85%tile</td>
<td>30</td>
<td>19</td>
</tr>
</tbody>
</table>

Figure 16 shows typical speed trajectories measured in the experiment period and before the experiment. One sees that the vehicle speed become around 10km/h near or on the speed humps. The value measured at middle point of each hump is around 20km/h to 25km/h. The humps ranged at around 20m keep vehicle speed lower.
3.2.2. Noise
Figure 17 shows average momentary values of noise produced by passing vehicles around humps. The graph explains that on the location of humps the noise decrease and after cars passing humps the noise increase. However, the 20m interval prevented vehicles from terrible reacceleration and the level of noise were restrained in the whole section where the humps were placed.

![Figure 17 Momentary value of noise](image)

3.3. Results of Resident Attitude Survey
This part explains the result of the resident attitude survey. Figure 18 shows answer to a question about noise issues during the experiment. The rate of respondents who answered “annoyed” or “somewhat annoyed” is only 11.9%. Figure 19 shows answers about permanent installation of humps. In the respondents who live along the subject street, 59.4% of the people answered “agree”, “agree with reservations” or “accept”. These results suggest that humps ranged at 20m did not have too big noise problems and the most residents accept the impact.

![Figure 18 How respondents thought about noise during the experiment](image)
4. CONCLUSION

This study aimed at finding appropriate interval of ranged speed hump from the viewpoint of noise and vibration as well as effect of speed reduction through experimental installation. First of all, it was, once again, found that sinusoidal humps cause little noise and vibration when cars pass over. It rather reduce noise as a result of the effect of speed reduction. Regarding the interval, it was found that 60m-interval can reduce speed less than 30km/h in all over the road section. The first experiment conducted in Kokubunji city, Tokyo seemed successful judging from observed data. However, residents along the experiment street complained noise problems in any cases of experiment. Cause of the noise was not the shock of traffic passing through humps but the re-acceleration of cars after passing humps. In the second experiment conducted in Bunkyo-ward, Tokyo, the intervals between humps were reduced to 20m to make drivers to "give up" to re-accelerate. Judging from the result of the questionnaire survey and noise observation, 20m-interval could control re-acceleration to the extent that residents along the road are acceptable. 

In this study, five different intervals of humps: 100m, 60m, 40m, 30m, 20m, were tested. Although the intervals are discrete and were chosen voluntarily, it may suggest a certain relationship between intervals and traffic calming effect. It would contribute to find appropriate intervals of ranged humps. Feasibility of installing humps frequently in local streets and Cost-Benefit of it will be the next challenges regarding humps. Especially, to establish methods to examine benefit from traffic calming projects should be an urgent issue.

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