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Rapid Measurements of Damaged Areas and Cavities Formed on Highways Caused by Heavy Rain Falls, Earthquakes or Similar Catastrophes

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Abstract

An abnormal damaged area and the volume of a deep cavity formed underneath this area on a highway cannot be measured correctly by any of the existing methods. However, in this study Bhattacharya's theorem was applied for the measurement of an abnormal area with success. An abnormal volume of the cavity formed underneath of this damaged area was also measured by a newly proposed rule of volume measurement. The authors hope that the theorem and the rule described in this paper can be applied in the measurements of various abnormal damaged areas and cavities of highways for quick restoration of the spots. In fact the method of area measurements as well as the measurements of volumes of the cavities formed underneath the area can be done in the small or large scale if needed. Measurements of volumes by filling method of the cavities by foam beads however can be removed from the cavities quickly by an electric vacuum suction machine and the beads are reusable many times.

Keywords: flow materials, uniform density, foam beads, damaged area, abnormal volume

1 Introduction

Serious damages on the surface of highways are often noticed after heavy rain falls, earthquakes, or similar causes of disasters. As a consequence, people suffer from the acute problems in the traffic. In this situation immediate restoration of the damages is needful. Additionally, prompt estimation of the loss is also important. Normally the measurements of simple bended damaged areas are done according to any of the existing methods, such as: - graphical method, the mid ordinate rule, the average ordinate rule or Simpson's rule [1,2,3,5]. But correct measurements of complicated areas with many bends and deflections are difficult to perform, because no method is known to us at present. In the past famous scientists namely, Archimedes (287 B.C-212 B.C), Newton (1643), Pythagoras (6th century B.C.), Ptolemy (2nd century A.D.), Euclid (3rd century B.C.), Heron of Alexandria (dates unknown) etc gifted their contributions in geometry of simple surface measurements but an accurate method for the measurements of complicated areas had never been reported. However a method was reported by Thomas Simpsons (1710-1761) which is presently a well-known method for the measurements of bended flat areas but Simpson's rule is sometimes difficult to apply when the areas appear to have many bends and deflections. Additionally, prolonged time is required to complete a measurement. As a matter of fact, a mathematical theorem has been reported recently based on Ghosh and Bhattacharya's principle which claims that correct measurements of all complicated areas are possible [2, 3, 6, 7]. The abnormal volumes of cavities formed on highways under the damaged areas can also be measured according to the newly proposed rule of volume measurements. The details of these measurements will be described in this paper

2 Methods and materials

Some special instruments were required for the study of alternative method of area and volume measurements such as: a photographic camera, a slide projector, a micro electric balance, a roll of polyethylene sheet (PES), a needle affixed with a pen which was connected with an electric heating device and a set of custom-made volume measuring containers. A damaged area on a highway was selected which was formed due to severe rainfalls followed by earthquake. Two photographs in the form of transparent slides were taken by a professional photographer from the appropriate high of a damaged area. One photographic slide was then projected vertically onto a large piece (40cm*60cm) of PES. This piece of PES was previously examined to confirm its special property of uniform density (2). This piece of PES was placed properly on a table and the bended curve line of the image of the damaged area was clearly focused on the PES. This image was then cut carefully and separated by an electrically heated needle. The cut piece was marked and weighed in an electric balance. This procedure was performed separately by an author and four surveyors. The average data were recorded in Table 1.

2.1 Measurements of the volume of a hollow space (cavity) formed underneath the damaged area of the road

After the area measurement was completed our next attempt was to measure the volume of the cavity. It was noticed that various forms of solid materials were present on the floor and some were attached on the walls of the cavity. So, this irregular shaped cavity was measured according to Bhattacharya's rule of volume measurement. This new rule claims that the volume of an irregular cavity (C) is directly proportional to the volume of filling material (fm) when its volume per unit mass is constant. This rule is briefly written as: $V_c \infty V_{fm}$ when the volume of (fm) per unit mass is constant. In this experiment three different types of materials were used separately as the fillers of the hollow space such as: water, dry sand and tiny beads of foam.

Water filling method:
In ancient time this method was originally invented by Archimedes (287 BC- 212 BC.). However this method is applicable only to measure the abnormal volumes by water displacement method as long as the sizes of the volumes are limited. We suspected that presence of invisible leakages inside the cavity. In spite of that we did this experiment rapidly and noticed

some loss of water was occurred during the fill up of the cavity. This procedure was considered to be simple as long as no leakage will be found in the cavity.
The water was evacuated by a pump machine. This was a lengthy and expensive procedure.

Dry sand filling method:
The damaged area was covered with a large piece of nylon cloth. Then strong packages made of nylon cloth were filled with known volumes of sand. These were dropped onto the cloth until the space was completely filled. Some known volumes of loose sand were used to cover the small spaces of the cavity. The total volumes of sand required to fill out the cavity were recorded which were considered as the volume of the cavity. Practically this procedure was easy and correct but long time was required to remove the sand from the cavity.

Foam beads filling method:
The large cavity was filled with known volumes of foam beads. This was an easy and prompt procedure for the measurements of abnormal volumes. These tiny beads were removed quickly from the cavity by suction device and were used repeatedly. These beads however do not absorb moisture and so its volume remained unchanged. This procedure cannot be used in windy weather. The tiny beads were extremely light which might scatter in all directions if it were handled carelessly, followed by pollution problem on the road. In spite of this simple problem, the authors considered this new procedure as a suitable method when many measurements were required to complete.

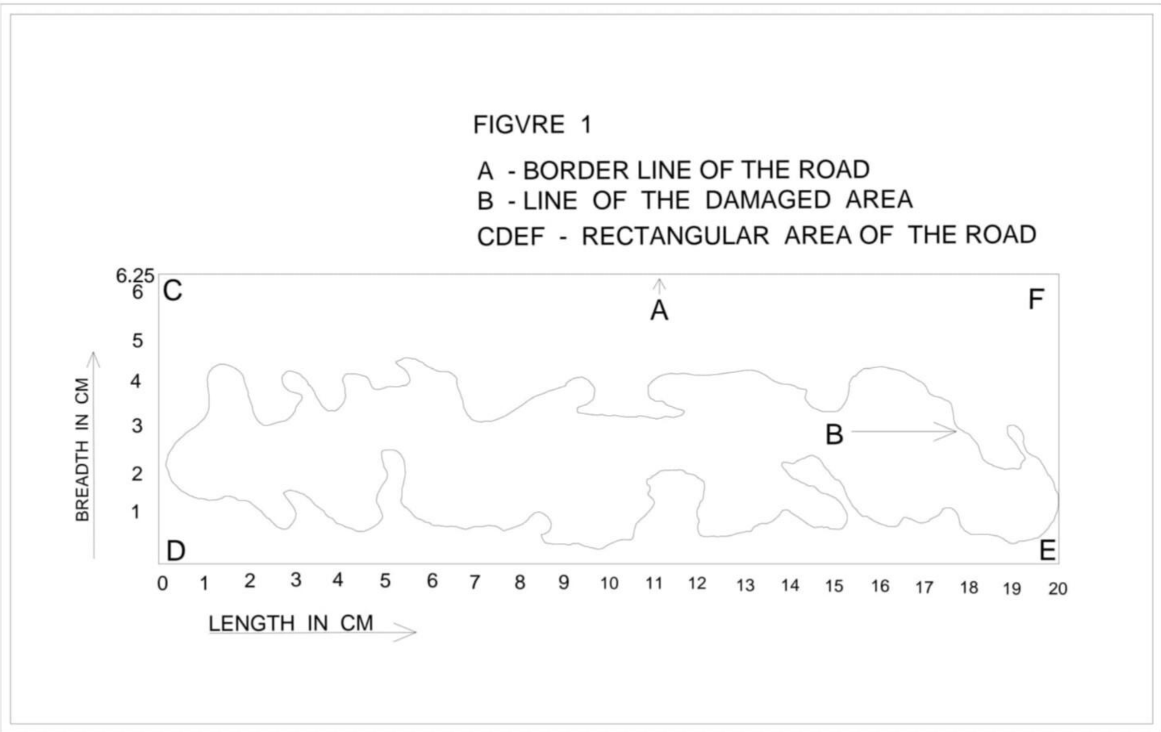

Figure 1: Diagram of the photographic image of the road including the damaged area. (Figure 1

indicates the irregular shape of the damaged area on the road. A = Border line of the road, B = Line of the damaged area, CDEF = A portion of the road (rectangular area)).

3 Results and discussion

Calculation of areas:

The measurements of the photographic images: The Gravitational weight (GW) of the piece of PES which was obtained from the photographic image of the rectangular area of the road including the damaged area= 0.92 gram (measured in a balance).

The GW of the piece of PES which was equivalent to the damaged area of the road only is 0.413 gram (measured in a balance).

The weight of 1 gram of PES= 1362 cm.

Hence, 0.92-gram PES will be equivalent to 136*0.92=1252 cm of PES. That is the area of the rectangular road including the damaged area.

The GW of the PES covering the damaged area only= 0.413 gram (determined by balance) which will be equivalent to 136*0.413=56.1682 cm.

Bhattacharya's Theorem is, I = W102 when I is the index and W is w1/w2, w1 = 0.413 gm weight of the photographic image of the bended area marked on PES and w2 = 0.92 gm weight of the image of the rectangular road marked on PES.

Therefore, W= 0.413/0.92 when expressed in percentage 0.413/0.92 * 100 = 44.9 % that is index I = 44. 9 % of the total area. (1)

Alternatively, we know 1 gm of PES = 1362 cm of PES

w1 = 0.413 gm of PES = 56.1682 cm of PES. w2 = 0.92 gm of PES = 1252 cm of PES. w1/w2 = 56.168/125 * 100 = 44.9 % = I (index). (2)

3.1 Calculation of the area of the road including of the damaged area at the original spot

This area was measured by a measuring tape and the following measurements were recorded:

The length of the area was measured = 320 cm and the breadth was 100 cm.The area should be 320*100 = 320002 cm

In the photographic image the area of a rectangle including damaged area was measured 1252 cm. Now if we divide 32000/125, we obtain 256. So the original spot area would be 256 times bigger than the area of the photographic image. The damaged area on the spot will be 56.25*256 = 144002 cm.

In Summary: Total original area of the road including the damaged area is 320002 cm and only the damaged area is 144002 cm.

Calculation of the volume of the cavity:

We know the area of the abnormal damaged portion is 144002 cm. In order to measure the volume accurately a custom made large plastic measuring container was used which was capable to measure 30 cm3 of flow material. The number of times of 30 cm3 of flow material which were required to fill out the cavity was recorded in table 2.

4 The statistical procedure

The standard deviation of the means and t-test for the significance at the level $P < 0.5$ were determined adopting the procedure described in SPSS Computer program. (4)

Table 1: Measurements of a damaged area on a highway. Data are expressed in square centimeter $\pm$ SD of the mean

Measurements of the photo images		**Direct measurements of the original spots**	
A rectangular portion of the road including damaged area. 125^2 cm ± 1.8	The damaged portion of the road 56. 25^2 cm ± 0.7	A rectangular portion including damaged area 32000^2 cm ± 00	The damaged portion of the road * 14400^2 cm ± 2.5

* Calculated from the data of photo image.

Table 2: Direct measurements of the hollow space formed underneath the damage area on a highway. Data are expressed in cubic centimeters $\pm$ SD of the mean.

Materials used to fill the hollow space.	Time required to completing the task in minutes.	Volumes of material required to fill the hollow space in cubic cm.	Remarks

Water	14.5 ±1.8	58*30 cm^3 ±4.7	This method is not applicable if there is any leakage present in the cavity. If water is found mixed with dirt cannot be reused. The data indicate the presence of an invisible leakage in the cavity.
Dry sand	16.2 ±2.5	49.8*30 cm^3 ±1.9	This is also an accurate method, but it is a lengthy procedure and costly. Complete evacuation from the cavity is possible and the sand can be reused.
Foam beads (pea shaped)	11.8 ±2.7	47.5*30 cm^3 ±2.1	This is an accurate, prompt and inexpensive method, but difficult to work in windy weather. Complete evacuation is easy by an electric vacuum suction method and the beads are reusable number of times.

5 Discussion

In our previous study we discussed in details about a correct method for the measurements of all kinds of abnormal areas. We used Bhattacharya's theorem for rapid determination of these areas (1,6). In this study we applied the same alternative procedure and were able to determine a damaged area on a highway which was noticed after a violent catastrophe. In this study we have included a new method of volume determination of an abnormal cavity which was found to exist underneath the same damaged area.

In reference to the volume measurement of abnormal cavities on highways some investigators believe that Ground Penetrating Rader (GPR) can be used for this purpose. We strictly object to this idea because GPR can only locate the hidden cavities if formed underneath a highway but unable to measure the exact volume. Therefore, we tried three different techniques to determine the abnormal volume of the cavity. We recorded nearly correct results of this volume measurement which was based on the concept of fill out the cavity with known volumes of filling material. When the area and the volume of a damaged portion of a road were known we were able to calculate the cost for restoration of the road. It is expected that not only the highways but also many spots of similar problem can be found in many other locations, such as: front and back yards of buildings, run ways of airports, playgrounds, rail road's, sea ports, coal mines and many other important locations. We hope that authorities of municipalities, corporations and even astronauts may be interested to use these techniques for rapid measurements of damaged locations. In summary, the innovations mentioned in this paper are: Rapid measurements of abnormal areas from the photo images and measurements of volumes by filling method of the cavity by selected filling material such as foam beads. These beads however can be removed from the cavity quickly by an electric vacuum suction machine and the beads are reusable many times.

6 Conclusion

All types of damaged areas on highways can be determine by the application of our newly developed theorem I=W102. The method is prompt, easy, economic and accurate in comparison to other existing methods. The novel idea of this study is that the determination of gravitational weight of the portion of a paper occupied by the photographic image of the damaged area can be converted to an area in square centimeters of the same portion of the paper and by applying simple method of calculation.

In addition to the determination of damaged area the volume of the cavity which was formed underneath the damaged area was measured on the concept of fill out the cavity with the known volume of filling material, such as foam beads. The authors hope that the theorem and the rule can be applied in various types of damaged areas as well as abnormal cavities for quick restoration of the spots.

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