Research on Crack Classification Method of Cement Concrete Pavement

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Abstract: Crack classification is always important content of crack detection. Unlike complex method on asphalt concrete, a simple crack classification method based on shape, size and geometry of crack is proposed. Cracks in cement pavement were divided into four types: corner cracks, longitudinal cracks, transverse cracks, broken plates in which there are the parallel-fractured type and the cross-fractured type, and the test show that the correct rate reach to 90%.

1. Introduction

Road crack classification has always been a research hotspot in road damage identification. Due to the wide variety of asphalt pavement damage and the degree of damage is difficult to describe with a unified analytical formula, most of them use complex nonlinear black box methods. For example, Kaseko[1] (1994), Chu Xiumin[2] (2004), Ding Ailing[3] (2007) and others have proposed classifier algorithms based on neural networks and support vector machines. The cracks on cement concrete pavement are very different from asphalt pavement. The classification method of cracks on asphalt pavement is too complicated and not conducive to popularization and application. Therefore, this paper discusses a simple and convenient geometric classification method for cracks on cement concrete pavement.

2. Crack Type of Cement Concrete Pavement

According to the shape and direction of the cracks, the cement concrete cracks are divided into four categories: corner cracks, transverse cracks, longitudinal cracks, and crushing plates. The crushing plates are divided into cross crack type and parallel crack type crushing plates, as shown in Figure 1.

(1) Corner crack
The crack occurs at the corner of the cement slab, and the position where it intersects the edge of the slab is less than half the length of the slab;

(2) Transverse crack
The cement panel is traversed by a single crack;

(3) Longitudinal crack
A single crack runs through the cement panel;

(4) Broken board
There are two or more cracks on the same cement panel. Generally, there are two basic forms, one is the intersection of the cracks, and the other is the approximately parallel cracks; the more complicated case is that there are both parallel cracks and cross cracks.
3. Criteria for Crack Classification

3.1. Discrimination Method of Corner Crack
As shown in Figure 2, there is a corner crack in the upper right corner of 2a, which is composed of two crack segments, and 2b is an index map. In the process of making the index map, because the two crack segments are adjacent, they are adjacent the two endpoints of are very similar and the cracks are in the same direction, so they are merged into a single crack in the index map, 2c is the schematic diagram of the circumscribed rectangle analysis of the index map. Assuming that the center of the image is the coordinate origin, the image is divided by the horizontal and vertical axes There are four quadrants. The circumscribed rectangle of the crack in Figure 2c is completely located in the first quadrant. The crack intersects two adjacent plate edges and meets the requirements of the corner crack definition. Therefore, it can be determined that this crack is a corner crack. The corner cracks are relatively simple to identify, as long as the extracted crack segments are indexed, and judging the location and size of the circumscribed rectangles of the cracks in the index map, the corner cracks can be located. The upper left and lower right corners of the circumscribed rectangles are required to be in the same quadrant, so that the location of the corner crack can be determined and the corner of the panel can be determined, and thus add the orientation element to the corner information, you can divide the corner crack more finely. In addition, special attention is needed to detect whether the crack intersects the adjacent board edge. A simple method is to calculate whether the line connecting the starting point and end point of the crack and its extension line intersect with the adjacent half edge. This line can be connected with the same direction. The diagonal of the rectangle is substituted.

3.2. Method for Discriminating Lateral Cracks
As shown in Figure 3, there is a horizontal crack in 3a, which is composed of three extracted crack segments, and 3b is an index map. In the process of making the index map, due to the two longer crack segments on the right Adjacent, so the two endpoints adjacent to each other are very close, the cracks are in the same direction. They are merged into a single crack in the index map; the leftmost crack is not merged. 3c is a schematic diagram of the analysis of the circumscribed rectangles of the cracks in the index map. The cracks with a smaller size on the left end are filtered out, and the longer length on the right side after the merger is retained. It is not difficult to see from the figure that the direction of the circumscribed rectangle can be used to determine this crack as a lateral crack. The identification of lateral cracks is also relatively simple. As long as the extracted cracks are indexed, and the location and size of the circumscribed rectangles of the cracks in the index can be completed. The method of discrimination for judging the cross-cracks in a single connected area with only one non-cross-crack in the image will be introduced in the next section; the width of its circumscribed rectangle is greater than its height, and it must be ensured that it is not a corner crack.
3.3. Method for Judging Longitudinal Cracks

As shown in Figure 4, there is a longitudinal crack in 4a, which is composed of two extracted crack segments. In the index map, these two adjacent crack segments with the same direction are merged to form a single connected area, as shown in the figure 4b. 4c is a schematic diagram of the analysis of the circumscribed rectangle of the index map. Similar to the judgment of the horizontal crack, the trend of the circumscribed rectangle can be used to determine this crack as a longitudinal crack. The criteria for determining longitudinal cracks are:

1. Single connected area
2. It is not a cross crack;
3. It is not corner crack / Angle of crack;
4. The height of the circumscribed rectangle of the connected area is required to be greater than its width.

3.4. Discriminating Method of Cross Crack Type Broken Plate

Cross cracks are formed by the convergence of more than two cracks. It often forms a single connected area in the image, which is easy to be misinterpreted as a horizontal or vertical crack. China's maintenance regulations stipulate that the impact area of a single crack is multiplied by the crack length and the impact factor (1m) calculation, and the impact area of the broken plate is the entire panel, and the wrong judgment of the crack type will cause a large calculation error. In addition, cross cracks have a large proportion in the road network, so the method of judging cross cracks will be discussed in detail.

The key to judging cross cracks is to find the intersection in the single connected area. The single connected area with the intersection must be a cross crack, and the intersection has the characteristics of corner points. The local area of the crack on the pavement is very complicated. This kind of complicated local trend change often forms a corner point, so the problem becomes how to find the corner point in the crack. Generally, after the crack is extracted, the crack has a certain width, and the extracted crack image needs to be refined to skeletonize the crack image. The skeleton image of the crack (refinement result) is composed of a single pixel width, basically inheriting the original crack, the direction of the image changes without changing the connectivity of the original image. The refined image is used for corner search. The calculation speed is fast, which greatly reduces the candidate solutions of the corner. More importantly, the width of the single pixel simplifies the subsequent, the complexity of intersection detection.

Thinning is an image processing operation that can shrink a binary image area into a line to approximate the center line of the area, also called a skeleton or epipolar line. The image of the crack
segment is not a single-line wide line after extraction and indexing, which is not conducive to searching for the intersection of the crack. The purpose of refinement is to reduce the image components until only the most basic information of the area, that is, the single-pixel wide line is retained. Figure 4.8c is the refinement result, which guarantees that the crack image of the detection result is only one pixel wide.

The intersection point of the cross crack has obvious corner characteristics, which can be detected by the corner detector. The Harris corner detector is a popular point of interest detector that has constant characteristics for rotation, light changes, and noise. And the amount of calculation is small. The Harris corner is obtained from the local block autocorrelation function of the signal. It is developed on the basis of the Moravec algorithm. The main difference between the two is the block movement.

![Figure 5](image)

**Figure 5.** Cross-crack type broken plate identification

As shown in Figure 5, 5a is the extracted crack segment image. The cross cracks in the figure have only one connected area. It would be wrong to simply judge this by the ratio of length to width and the location of the enclosing rectangle; 5b is the index map; 5c is Refining the index map, the basic geometric features of the cracks in 5b are retained in the map, which is single pixel wide. Since the size of the index map is only 0.16% of the original image (the grid size is 25 × 25), The calculation amount of the thinning algorithm is not large; corner detection and intersection detection are done for 5c in the 5d picture. The small red circle in the figure is the corner detection result. The corner exists at the intersection, the local crack of the fracture is abrupt and refined After the additional short branch. After finding the corner point, it is easy to realize the detection of the intersection point, and use the position of the corner point as the center of the circle to make a detection circle, the radius is not less than 20 pixels (equivalent to the actual size of the road surface 0.5m), as shown by the green circle in Figure 5d. The circumference of the detection circle at the location has at least 3 intersections with the crack, and there are only 2 or 1 intersections at other corner points. When the detection circle exceeds the image boundary, the radius of the detection circle can be appropriately reduced. Considering that there may be additional short branches in the refined image in the actual detection process, the radius should not be less than 10 pixels.

3.5. **Discrimination Method of Parallel Crack Type Broken Plate**

Sometimes there are multiple crack segments on the cement panel. Are they all belong to one crack or are they formed by multiple cracks? As shown in Figure 6, there are 9 crack segments in Figure 6a; Figure 6b is an index map; in the process of making an index map, some adjacent crack segments are connected; Figure 6c is an external rectangular box of the index map, only three longer branches are reserved. For the case where there are many crack fragments, the shorter crack fragments need to be filtered. The filtering criterion is that the crack fragments are not corner cracks and the length is less than one-fifth of the image width. The width is approximately equivalent to the actual size of the road surface of 0.6m, that is, ignoring small crack fragments below 0.6m. The crack segments 1 and 2 in 6c belong to the same crack, and cannot be judged arbitrarily by simple crack segment counting. There are multiple cracks on the panel, and the location and crack direction of each crack segment should be further analyzed.

First, calculate the circumscribed rectangle of each fracture segment, and then determine the approximate trend of each fracture segment by the aspect ratio. If the height is greater than the width, the fracture segment is considered to be a longitudinal crack; otherwise, it is judged as a lateral crack.
Next, three situations are discussed based on the type of fracture segments.

In the first case, if the fracture segment has a single strike type, that is, all fractures are either transverse or longitudinal fractures. Do vertical overlap analysis for each transverse crack. The so-called vertical overlap analysis is to compare whether the circumscribed rectangles of the current crack segment and other crack segments overlap in the vertical projection. As shown in Figure 6c, there is longitudinal overlap between fracture fragment 1 and fragment 3, it can be inferred that there are at least two cracks in the panel; similarly, for each longitudinal crack to do lateral overlap analysis. Considering the variability of the crack trend, in order to improve the accuracy of judgment, a threshold of overlapping area is set, which is a quarter of the image width, which is about 0.8m of the actual road surface size. For images smaller than this threshold, it is judged as a single crack, and the crack type is determined according to the aspect ratio.

In the second case, for cross cracks, sometimes the cross-crack segments on the panel do not form a connected area, and in the cross-point detection described in the previous section, some cracks at the cross point are too small and are missed. At this time, we can continue to judge by the type of crack on the panel, that is, when there are both horizontal crack segments and vertical crack segments on the panel, the circumscribed rectangle of adjacent crack segments represents the diagonal of crack strike for angle analysis. The existence of an angle less than 90 degrees is judged as a cross crack, otherwise, it is judged as a single crack, and the crack type of the image is determined according to the aspect ratio of the longest crack segment.

In the third case, when there are both cross-type cracks and parallel cracks on the panel, it is judged as cross cracks.

![Figure 6](image)

**Figure 6.** Recognition of parallel cracked broken plates

4. **Classification Results**

In order to verify the reliability of the classification algorithm, the cracks of about 18.2Km in K584 ~ K603 section of GA80 highway in Guangxi were classified. The results are listed in Table 1. From the table, the classification accuracy of corner cracks, lateral cracks, longitudinal cracks and parallel cracks is higher, all exceeding 90%, and the recognition rate of cross cracks is low, but close to 90%. Overall, the classification effect is better.

| Cracks Type         | Number of plates | Recognize the number correctly | Correct rate(%) |
|---------------------|------------------|--------------------------------|-----------------|
| Angle of crack      | 243              | 223                            | 92              |
| Transverse crack    | 307              | 282                            | 92              |
| Longitudinal crack  | 333              | 316                            | 95              |
| Cross crack         | 243              | 216                            | 89              |
| Parallel crack      | 155              | 142                            | 92              |

5. **Conclusion**

Cement pavement cracks are divided into four types: corner cracks, longitudinal cracks, transverse cracks, and broken plates, of which there are two types of broken plates, parallel crack type and cross crack type, and their respective image criteria are given. The large sample test proves that the method of discriminating crack types described in this paper is feasible.
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