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Two-stage identification of interlayer contact loss for CRTS III prefabricated slab track based on multi-index fusion

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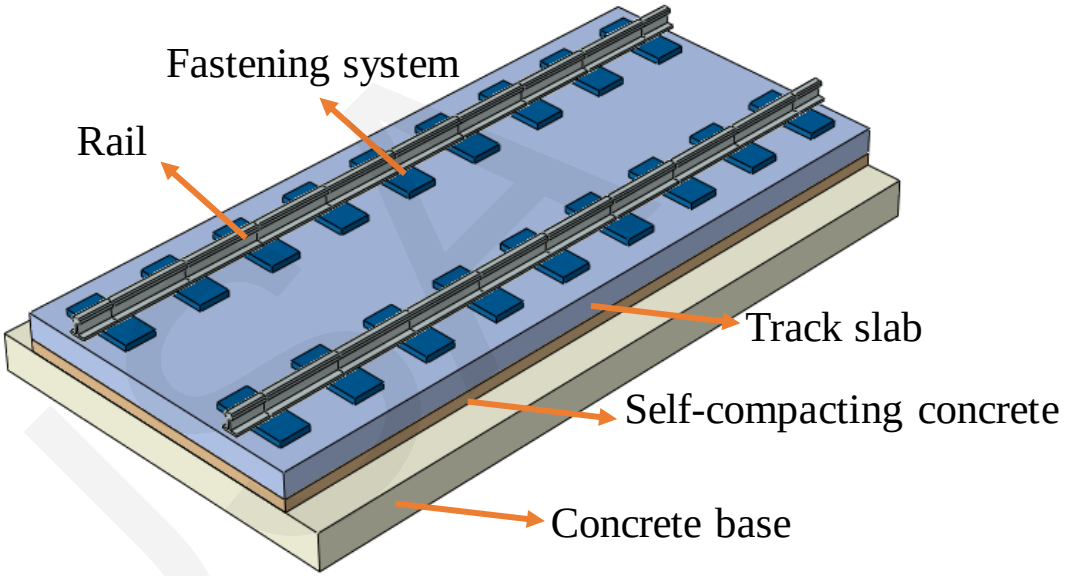
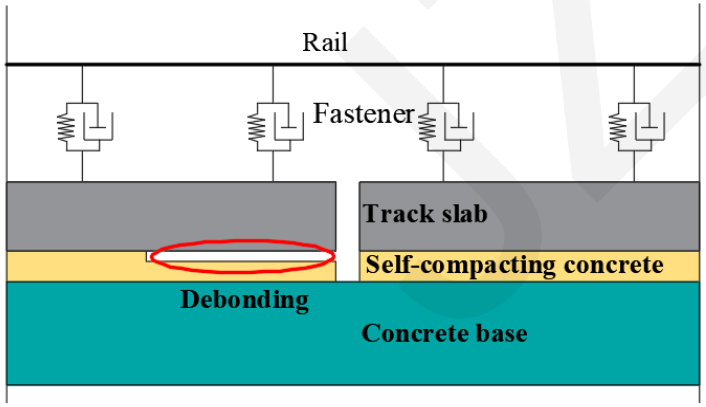
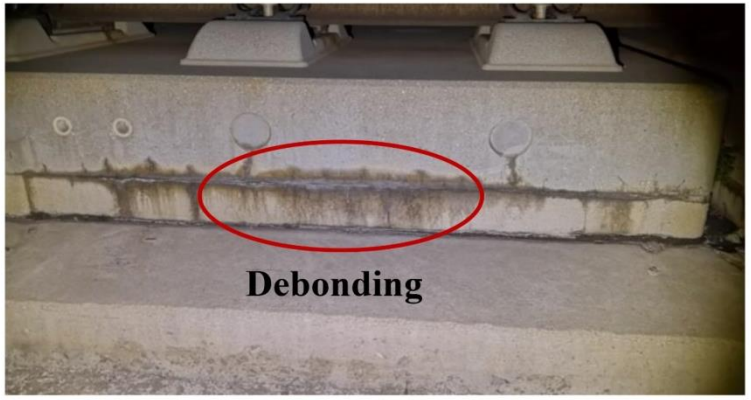
1. Research subjects



Structural composition of CRTS III prefabricated slab track



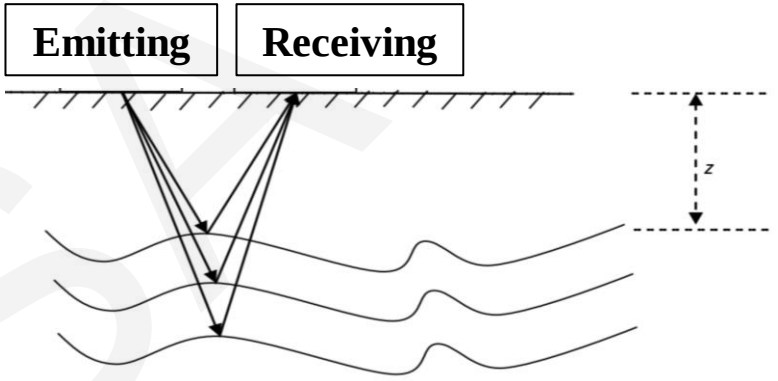


Interlayer debonding between the track slab and SCC

2. Traditional damage identification methods

Method 1: Ground-penetrating radar (GPR)

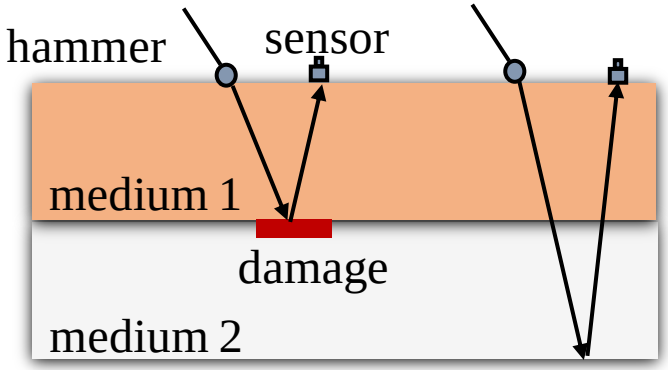
- reflection and scattering of electromagnetic waves;
- the influence of the reinforcement bar;
- errors during manual image recognition;
- low accuracy of damage identification



Principle of GPR method

Method 2: Impact-echo (IE)

- single-side detectability;
- intuitive detection results;
- low influence by steel bars;
- low efficiency due to many impact points

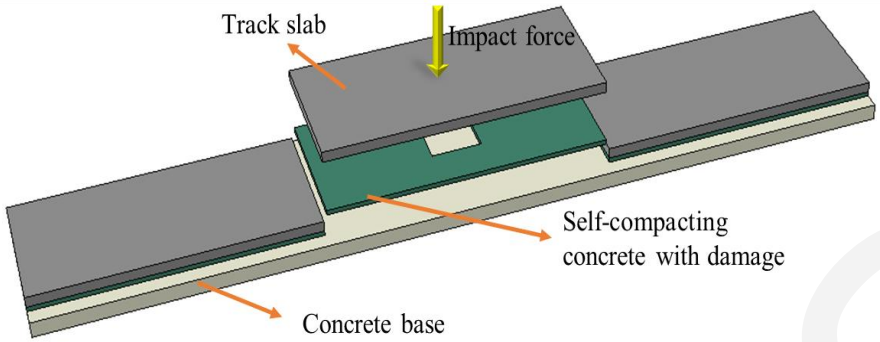


Principle of IE method

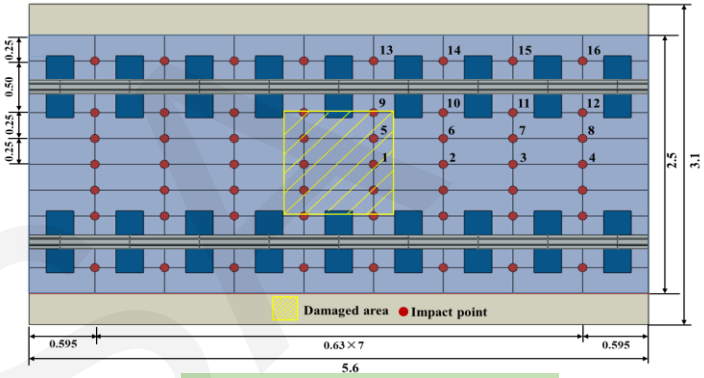
The existing traditional methods have some limitations, so the **transient impact method** is proposed to identify the interlayer damage.

3. The process of two-stage identification method

Transient impact model of III prefabricated slab track



Calculation model



Impact point layout

Analysis of damage indices

Time domain

- Evidence 1: Peak-peak value
- Evidence 2: Absolute mean value

Frequency domain

- Evidence 3: Mean amplitude
- Evidence 4: Maximum amplitude
- Evidence 5: Power density ratio

D-S evidence theory

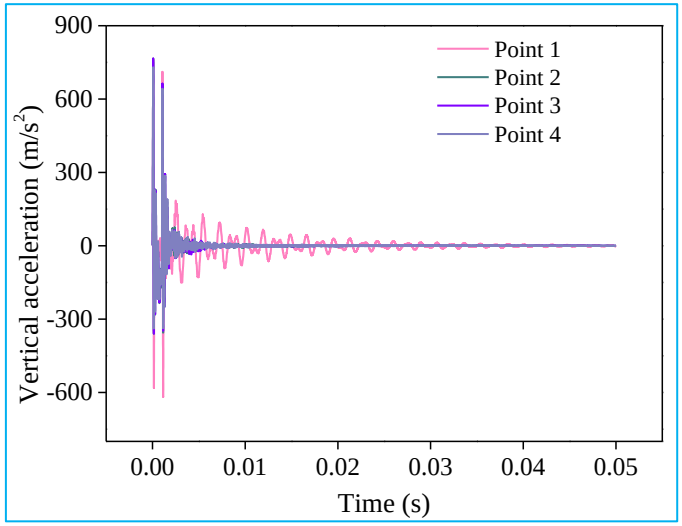
Kriging interpolation method

Stage I: Approximate identification

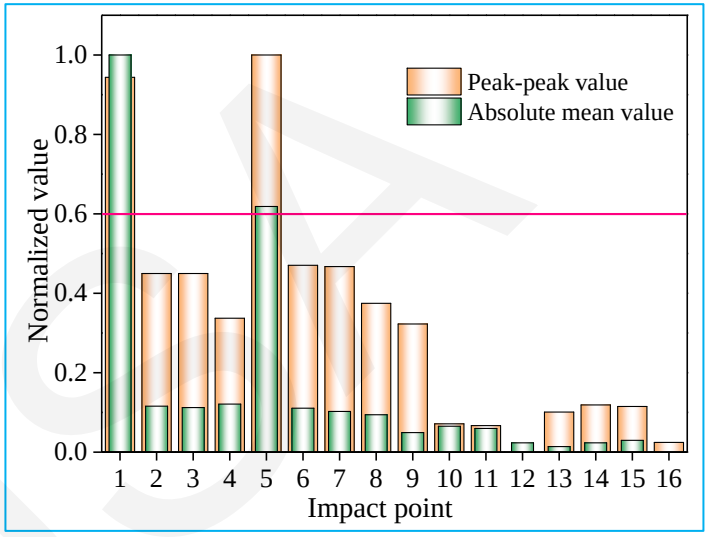
Stage II: Precise identification

2D/3D defect images and identification accuracy are obtained

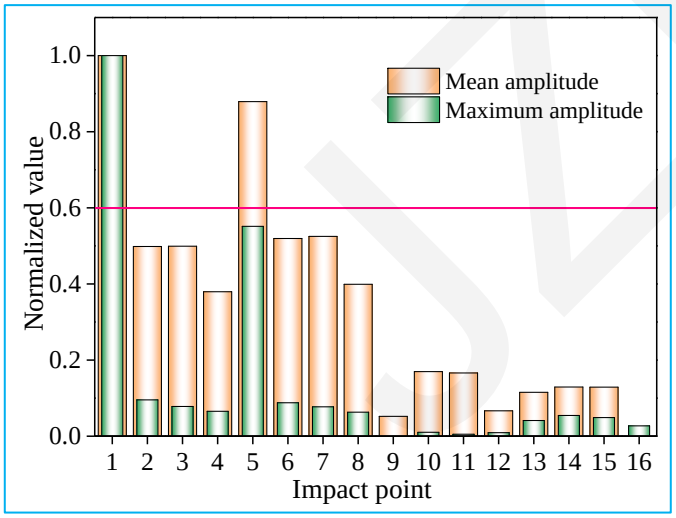
3.1 Analysis of damage indices

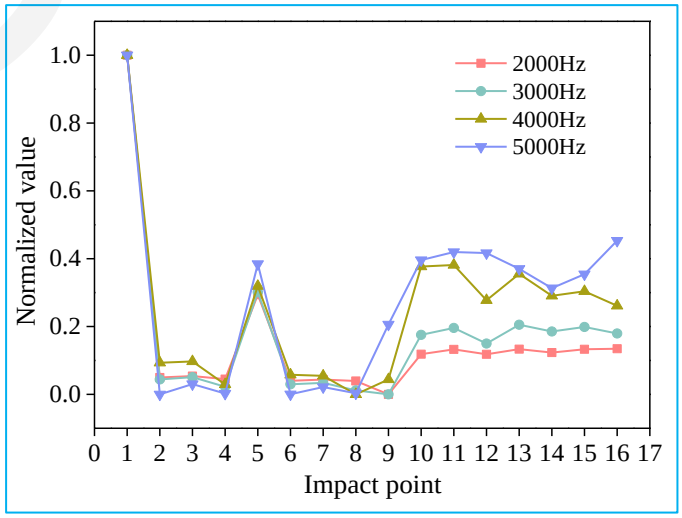


Vertical acceleration curves



Damage indices in time domain





Damage indices in frequency domain

3.2 Stage I: Approximate identification

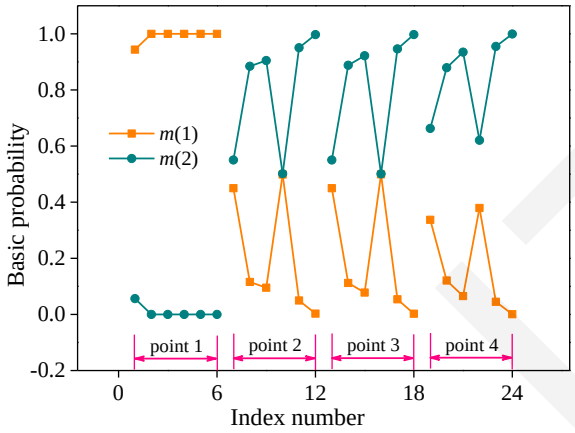
Main functions of D-S evidence

$$\begin{cases} m(\varnothing) = 0 \\ m(A) = \dfrac{1}{1-k} \sum\limits_{A_i \cap C_j = A} m_1(A_i) m_2(C_j) \\ k = \sum\limits_{A_i \cap C_j = \varnothing} m_1(A_i) m_2(C_j) \end{cases}$$

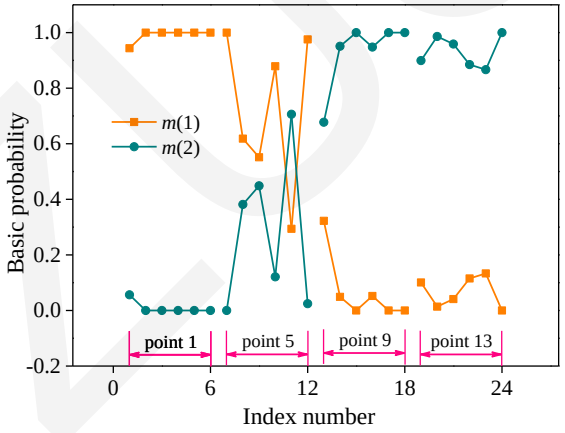
BPA calculation of each focal element

$$m_n(A_i) = z_n(A_i) \Big/ \sum_{n=1}^{5} z_n(A_i)$$

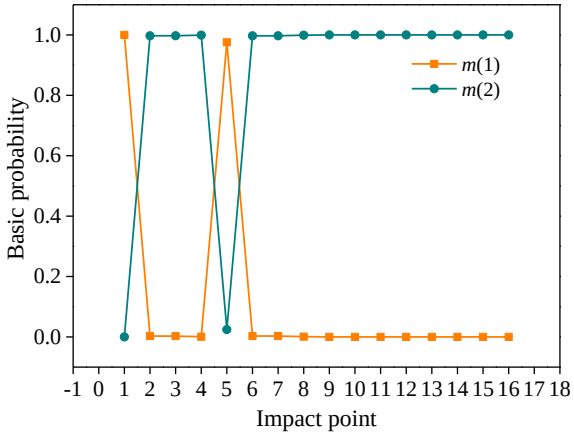
$$z_n(A_2) = 1 - z_n(A_1)$$



(a) Longitudinal



(b) Lateral

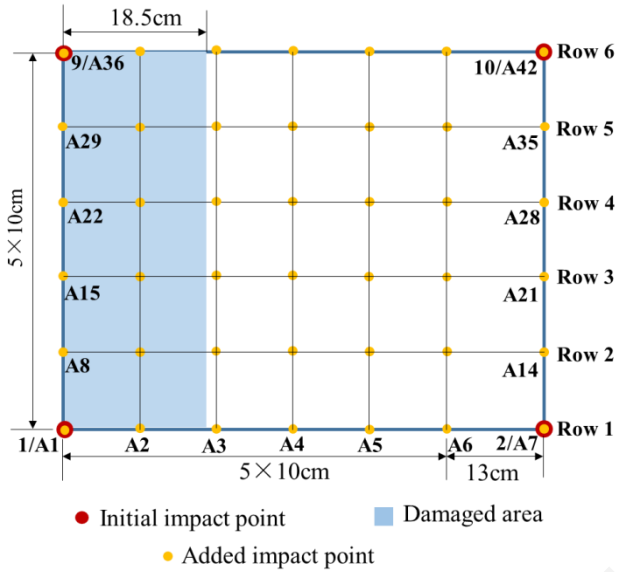


(c) All points

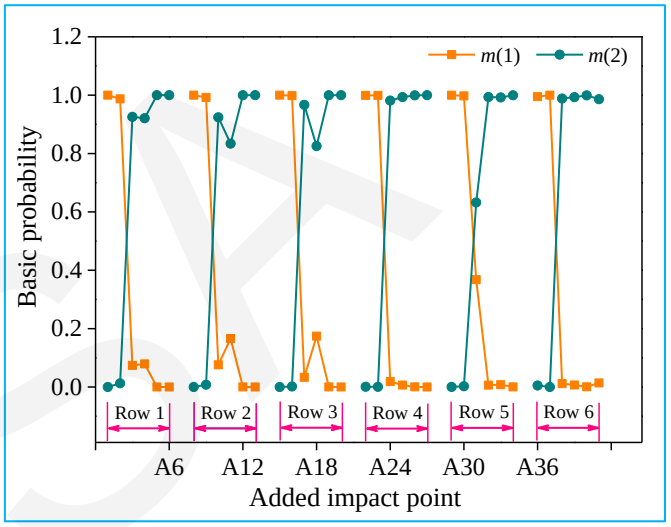
Fusion results of damage indices at different impact points

Results: Impact points 1 and 5 are damaged, and the rest of points are undamaged. It is basically consistent with the set-up damage conditions.

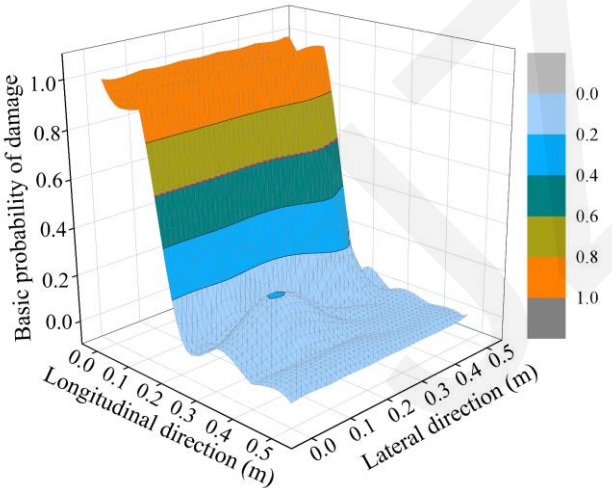
3.3 Stage II: Precise identification



Layout of added impact points



Index fusion results



2D defect imaging with accuracy of 81.1%

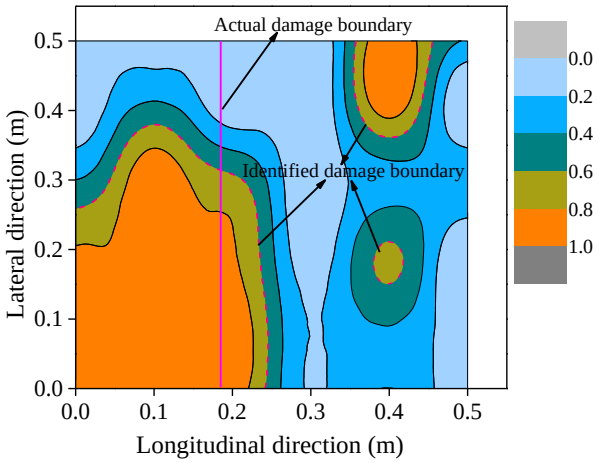
Identification accuracy: $\eta = \frac{S_{in}}{S} - \frac{S_{out}}{S}$

S the area of the actual damaged area, taken as 0.0925 m^2.

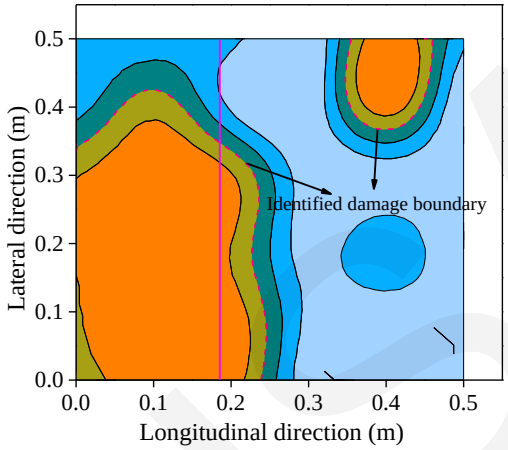
S_{in} the area where the predicted probability of damage is greater than 0.6 within the actual damaged area.

S_{out} the area where the predicted probability of damage is greater than 0.6 outside the actual damaged area.

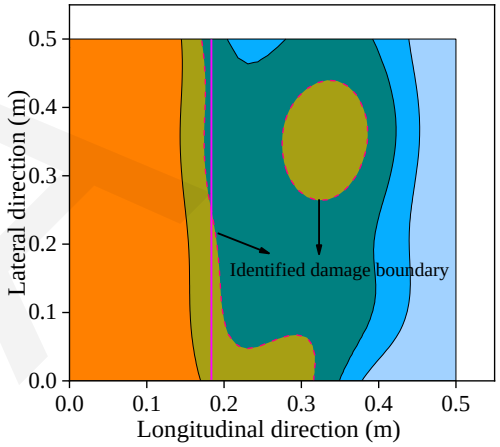
4. Effect of different damage degrees on identification



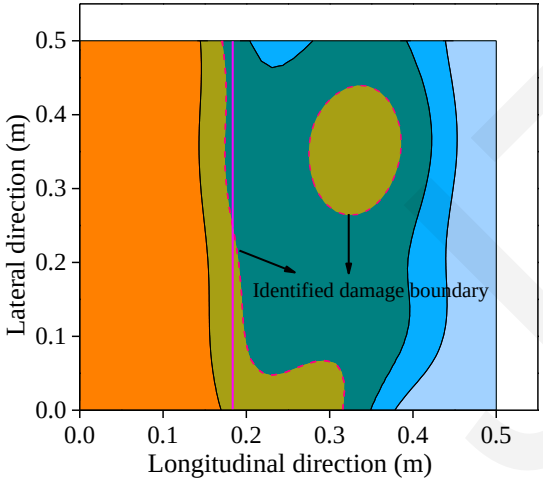
(a) Damage degree: 20%



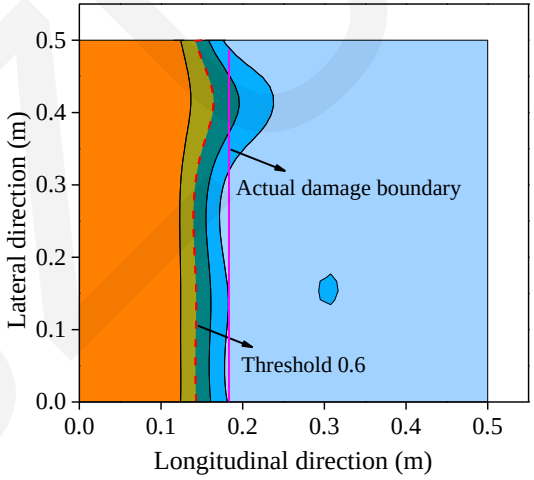
(b) Damage degree: 40%



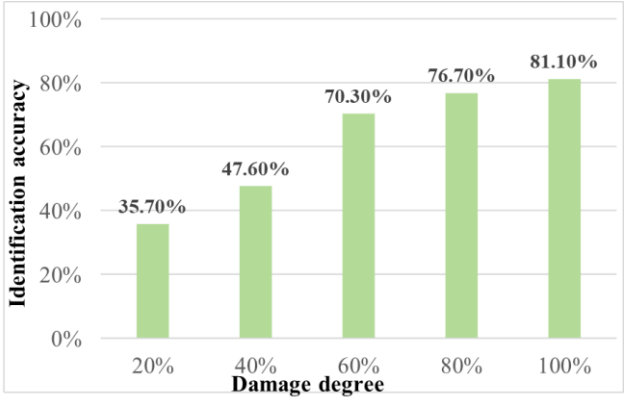
(c) Damage degree: 60%



(d) Damage degree: 80%



(e) Damage degree: 100%



(f) Identification results

Identification accuracy under different damage degrees

5. Conclusions

- A single damage index cannot effectively judge the presence or absence of damage at the impact point, and the accuracy cannot be guaranteed.

- After the damage indices are fused based on the evidence theory, the complementary information of various damage indices can be fully utilized, which reduces the uncertainty of identification. For stage I, the location of the damaged area can all be roughly identified by fusing five damage indices of acceleration under different degrees of contact loss.

- For stage II, when the degree of contact loss is under 50%, the “precise identification” does not secure an accurate identification, but when this value is larger than 50%, the contact loss identification accuracy can reach 70% to 80%, which is ideal. The identification method proposed in this paper offers theoretical supports for the maintenance and repair of slab tracks.