Ground Penetrating Radar Detection of Steel Rebar Corrosion in Concrete Specimens

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Introduction

Concrete rebar corrosion is a major safety risk, inducing section loss and stress concentration, which leads to cracks and spalling (Fig. 1). Ground-penetrating radar (GPR), can locate rusted steel rebars for condition assessment and quantification.

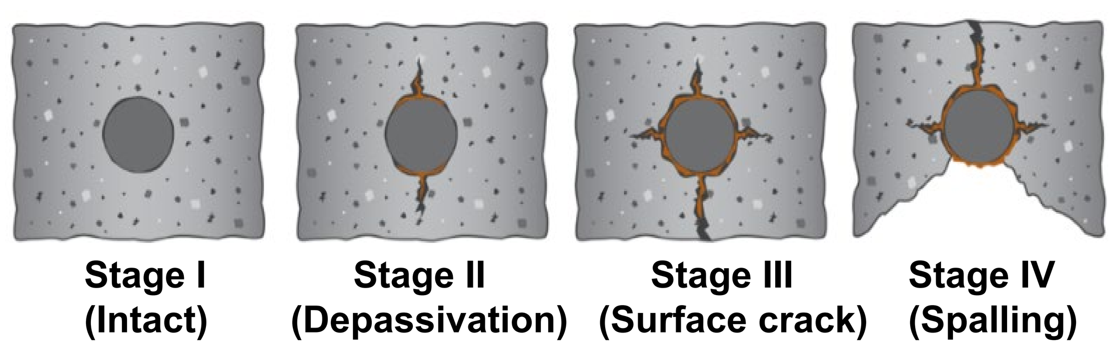

Fig. 1. The four Stages of steel rebar corrosion In concrete structures.

Objective

To assess the feasibility of a 1.6GHz GPR (by GSSI) for corrosion detection and quantification, by observing the changes in geometry (i.e., scattering response), and amplitude. The impacts of scan position and angle are studied beforehand.

Experiment

Three 12 x 12 x 5 in^3 RC panels were cast with a #5 rebar at the center. Chloride-induced corrosion was introduced to two specimens via the accelerated corrosion test (ACT) forming stage II & III specimens. The GPR dielectric constant (ϵ_r), was set to 5.0. The scan setup is shown in Fig. 2

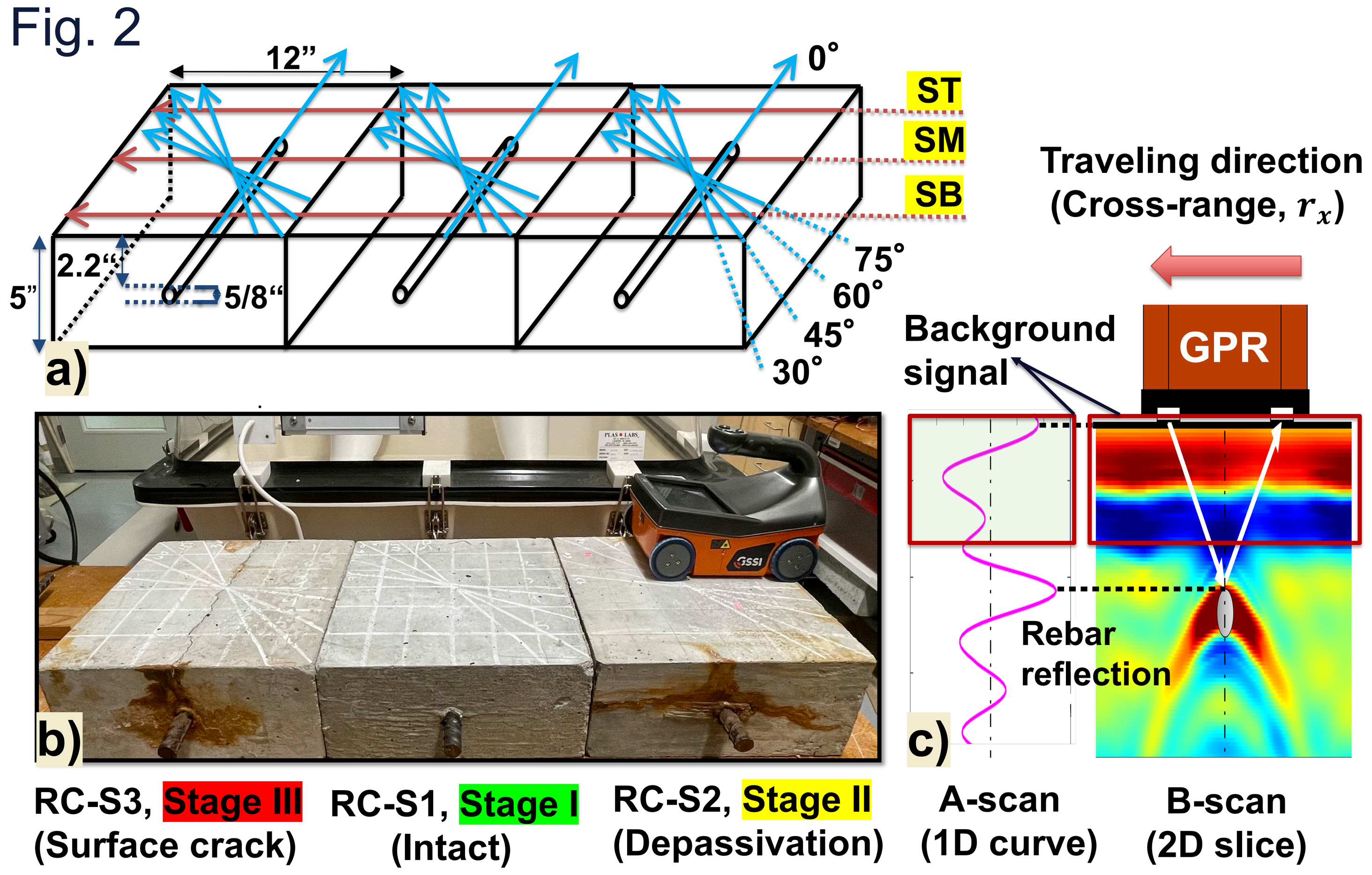

Fig 2. a): Scan setup; b): 1.5GHz GPR scanning the RC specimens; c): B-scan image of a rebar (right), and the A-scan curve along the hyperbola apex.

Results

Scattering Response: Corner scattering effect

The response is analyzed by comparing the background signals of the horizontal B-scans, SM (middle), ST (top corner), and SB (bottom corner) and extracting the range (r_{max}) values of local amplitude extrema (I_{max}), along each A-scan curve in the cross-range (r_x), direction (Fig. 3).

$$r_{max} = r[(r)_j, \forall j \in [1, b-2] \mid I_{((r_x)_i,(r)_j)} < I_{((r_x)_i,(r)_{j+1})} \wedge I_{((r_x)_i,(r)_{j+1})} > I_{((r_x)_i,(r)_{j+2})}] \quad \textbf{(1)}$$

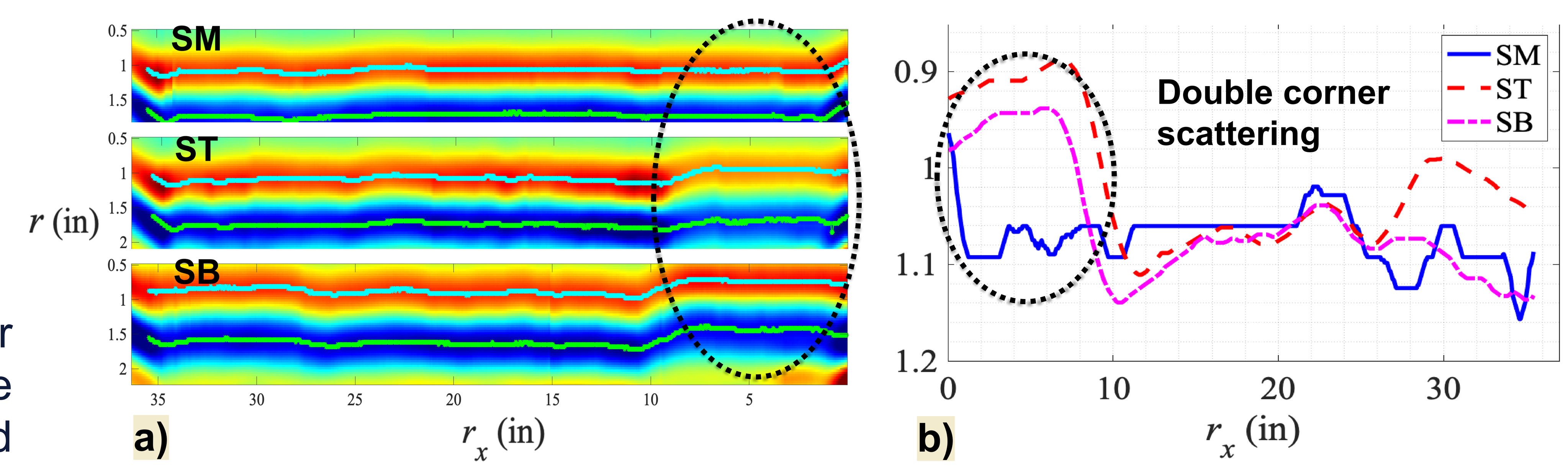

Fig. 3. Background signals of SM, ST, and SB B-scans: a): Raw B-scans; b): Feature-extracted.

Geometric scattering impact of scan angle and stage of corrosion

The rebars' hyperbolic-shaped reflection coordinates at 6 scan angles for each specimen are extracted using Eq. 1 and modeled by 2nd-degree polynomials, to study the impacts of scan angle and stage of corrosion on Average curvature (κ_{avg}), and the characteristic width coefficient (W_c), defined as the inverse of coefficient of x^2, are directly (linear), and inversely (exponential), related to the scan angle (θ), with respect to the rebars (Fig. 4).

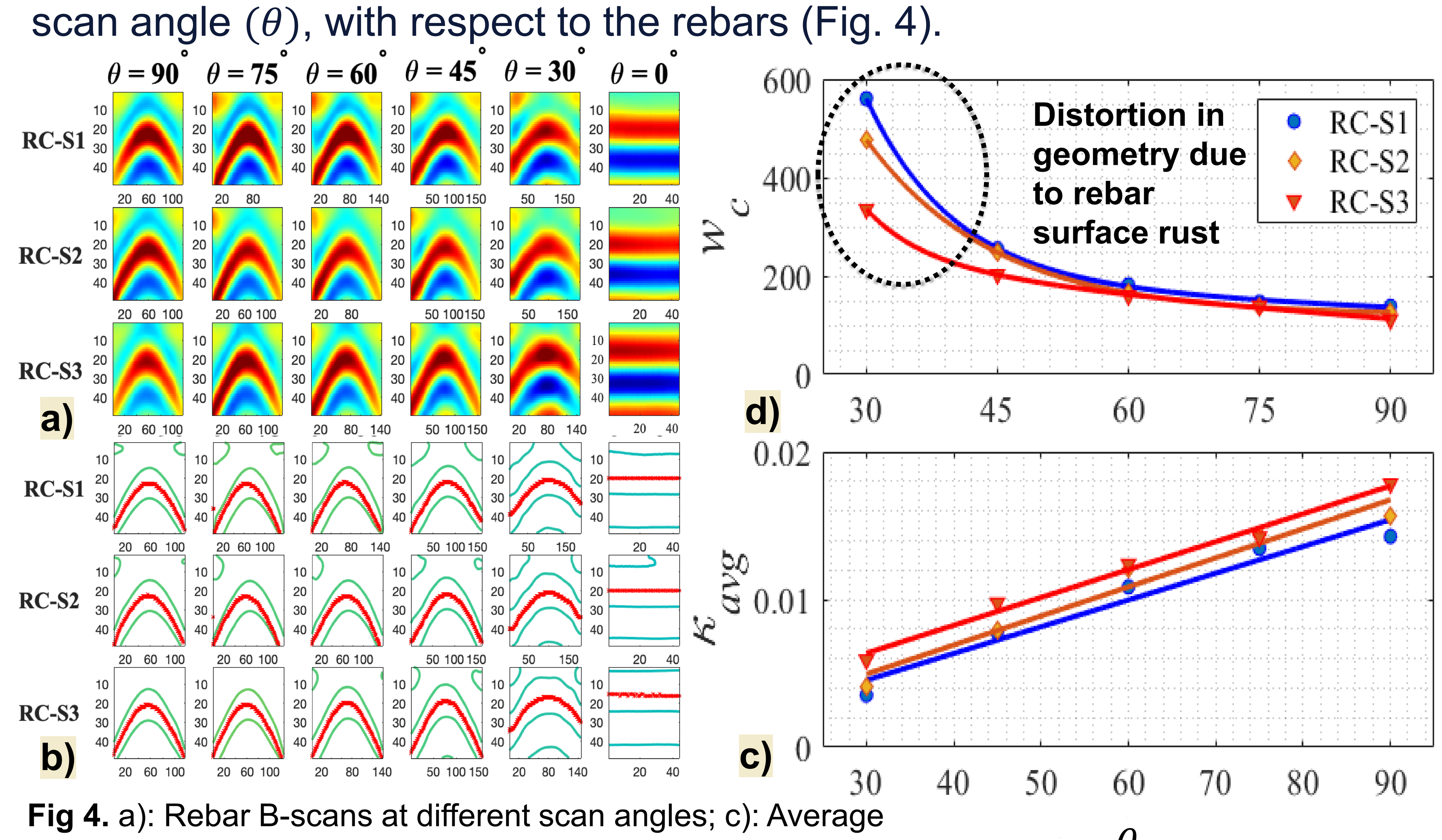

Fig 4. a): Rebar B-scans at different scan angles; c): Average curvature vs. scan angle; d): Characteristic width vs. scan angle

Table 1. Parameters of the numerical models.

Specimen	Equation	R^2
RC-S1	$W_c(\theta) = 7637e^{-0.101\theta} + 226e^{-0.005664\theta}$	0.99
	$\kappa_{avg}(\theta) = 0.00018120 - 0.0009022$	0.949
RC-S2	$W_c(\theta) = 2727e^{-0.0674\theta} + 113.2e^{0.000678\theta}$	0.99
	$\kappa_{avg}(\theta) = 0.00019670 - 0.0009478$	0.961
RC-S3	$W_c(\theta) = 11470e^{-0.1563\theta} + 327.5e^{-0.01179\theta}$	0.99
	$\kappa_{avg}(\theta) = 0.00018880 - 0.0007017$	0.986

Impact of corrosion on rebar response amplitude

The perpendicular middle scan (SM), is used to analyze reflected amplitudes of the RC rebars. Corrosion reduces the local maxima and absolute maximum reflection amplitudes (Fig. 5), due to formation of rust.

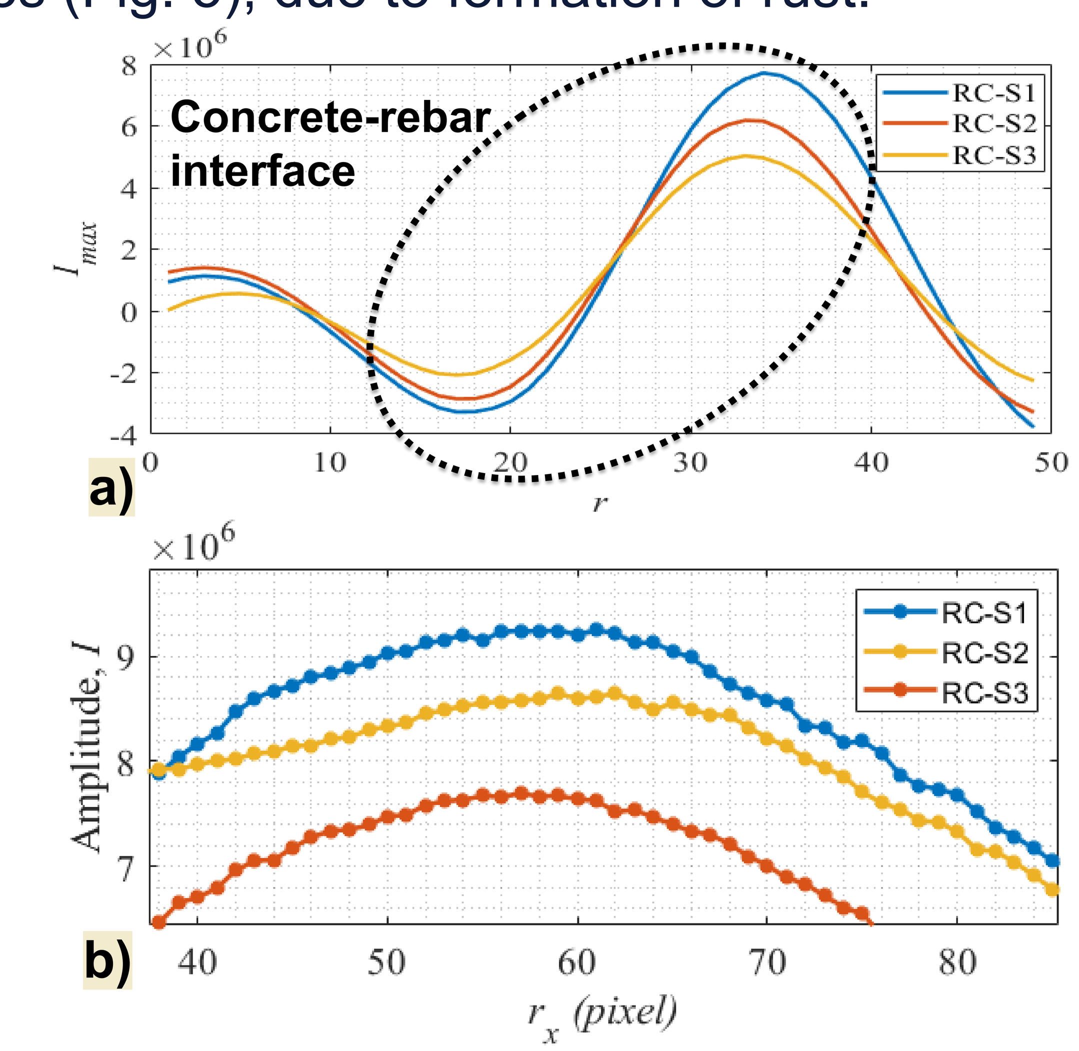

Fig 5. a): A-scans at the hyperbola apex of each rebar; b): Amplitude profile.

Conclusion

- The ideal B-scan of a rebar is conducted farthest from the edges (such as the middle), at $\theta = 90°$.
- The presence of steel rebar corrosion in RC structures can reduce the GPR amplitude and change the scattering pattern (geometry) of the B-scan images of the rebars.

References:

K. Raisi, NK, TY, SPIE Conference, 2022, CA, USA

K. Raisi, NK, TY, EMI Conference, 2022, MD, USA