Evaluating Mechanical and Durability Performance of Recycled Plastic-rubber Compound Modified Mortars with/without Tire Steel Fiber-Reinforcement

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Presentation Outline

- Motivations and objectives
- Development of Plastic-rubber (PR) Compound Modified Mortars with/without Tire Steel Fiber-Reinforcement (PRM and PRSRM)
  - Mixture design of PRM and PRSRM
  - Mechanical strength of PRM and PRSRM
  - Effects of added steel fiber on the flexural-fracture mechanical properties
  - Shrinkage measurement of PRM and PRSRM
- Conclusions
- Acknowledgment

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Motivations

- The landfilling is becoming unacceptable and costly due to limited available sites for waste disposal and its pollution to soil and ground water
- The application of concrete containing waste tire rubber and plastics is still limited due to reduced strength and low interface bonding
- The waste plastics and rubber can be manufactured to form higher stiffness plastic-rubber (PR) compound
- The waste tire fiber reinforcement could be used to improve the fracture and durability properties of compound modified mortar

http://www.wastetireoil.com/Pyrolysis_plant/recycling_plant/waste_tire_recycling_plant_178.html

Objectives

Objective:

Development of Plastic-rubber (PR) Compound Modified Mortars PRM and Tire Steel Fiber-Reinforced Compound Modified Mortars (PRSRM)

1. Develop Plastic-rubber (PR) Compound Modified Mortars PRM and Tire Steel Fiber-Reinforced Compound Modified Mortars (PRSRM) based on the investigation of fresh performance, hardened property, and shrinkage resistance
2. Investigate fracture behaviors of PRM and PRSRM samples and the combined effects of PR compounds and steel fibers by flexural test on notched beam

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Materials preparation and mixture design

PR compound particles

Ingredients:

60%: Thermoplastic polyolefin (PP and PE)

40%: #80mesh rubber from tires

Size:

About 2*3*4mm cylinders

Recycled steel fiber

Size range:

Length: 5-30mm

Diameters: 0.1-0.4mm

Materials preparation and mixture design

Mechanical Properties of PR Compounds

			Tensile Properties (500 mm/min) ASTM D412/ASTM D638			Flexural Properties ASTM D790	
Material	Density (g/cm^3) ASTM D792	Hardness (Shore A) ASTM D2240	Tensile strength (MPa)	Elongation @ Break (%)	Tensile Modulus (MPa)	1% Secant Modulus (MPa)	Flexural Strength (MPa)
CRTPE-85	0.969	85	8.7	294	39	76	2.7

Materials preparation and mixture design

Three different PR compound volumes:
5%, 10%, and 15% (based on #8 sand volume percentage);
One steel fiber volumes:
0.5%

Mixing procedures:

1. Dry mixing with all aggregates and rubber (if any): 0.5 min
2. Add the tap water and steel fiber (if any), and mixing:3 min
3. Rest for 3 min
4. Final mixing: 2 mins

Mixture designs of mortar samples (Unit: kg/m^3)

Sample types	Designed compound Content (vol. %)	Designed Fiber Content (vol. %)	Designed w/b	Water	Portland cement	#8	#16	#30	#50	#100	PR	Steel Fiber
C(without PR and fiber)	0.00	0.00	0.47	224.00	477.00	108.00	271.00	271.00	271.00	162.00	0.00	0.00
5PR (with 5% PR)	5.00	0.00	0.47	224.00	477.00	102.60	271.00	271.00	271.00	162.00	2.36	0.00
10PR (with 10% PR)	10.00	0.00	0.47	224.00	477.00	97.20	271.00	271.00	271.00	162.00	4.72	0.00
15PR (with 15% PR)	15.00	0.00	0.47	224.00	477.00	91.80	271.00	271.00	271.00	162.00	7.07	0.00
C05S(with 0.5% fiber only)	0.00	0.50	0.47	224.00	477.00	108.00	271.00	271.00	271.00	162.00	0.00	8.05
5PR05S (with 5% PR and 0.5% fiber)	5.00	0.50	0.47	224.00	477.00	102.60	271.00	271.00	271.00	162.00	2.36	8.05
10PR05S (with 10% PR and 0.5% fiber)	10.00	0.50	0.47	224.00	477.00	97.20	271.00	271.00	271.00	162.00	4.72	8.05
15PR05S (with 15% PR and 0.5% fiber)	15.00	0.50	0.47	224.00	477.00	91.80	271.00	271.00	271.00	162.00	7.07	8.05

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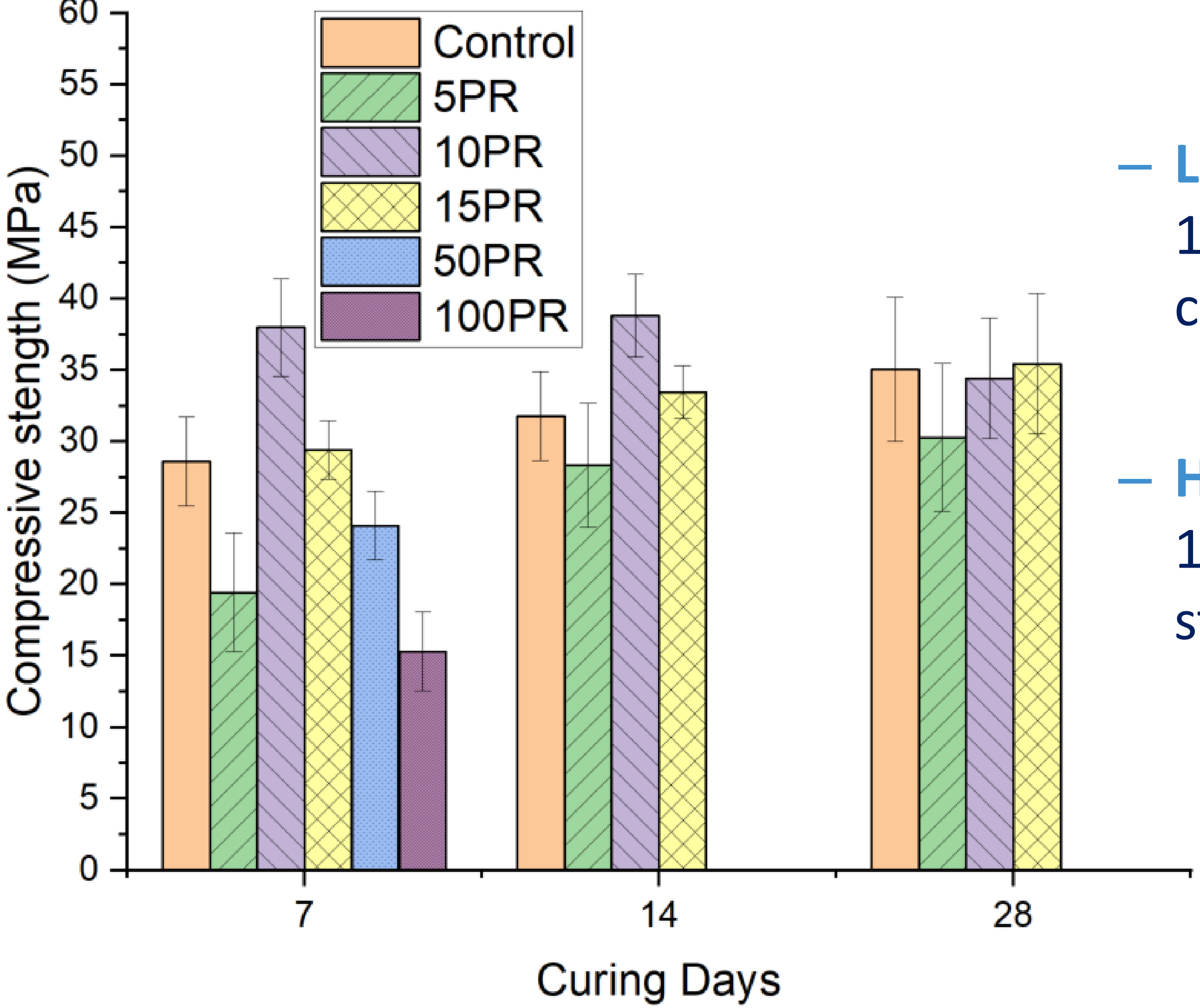
Mechanical properties evaluation

- Compressive strength

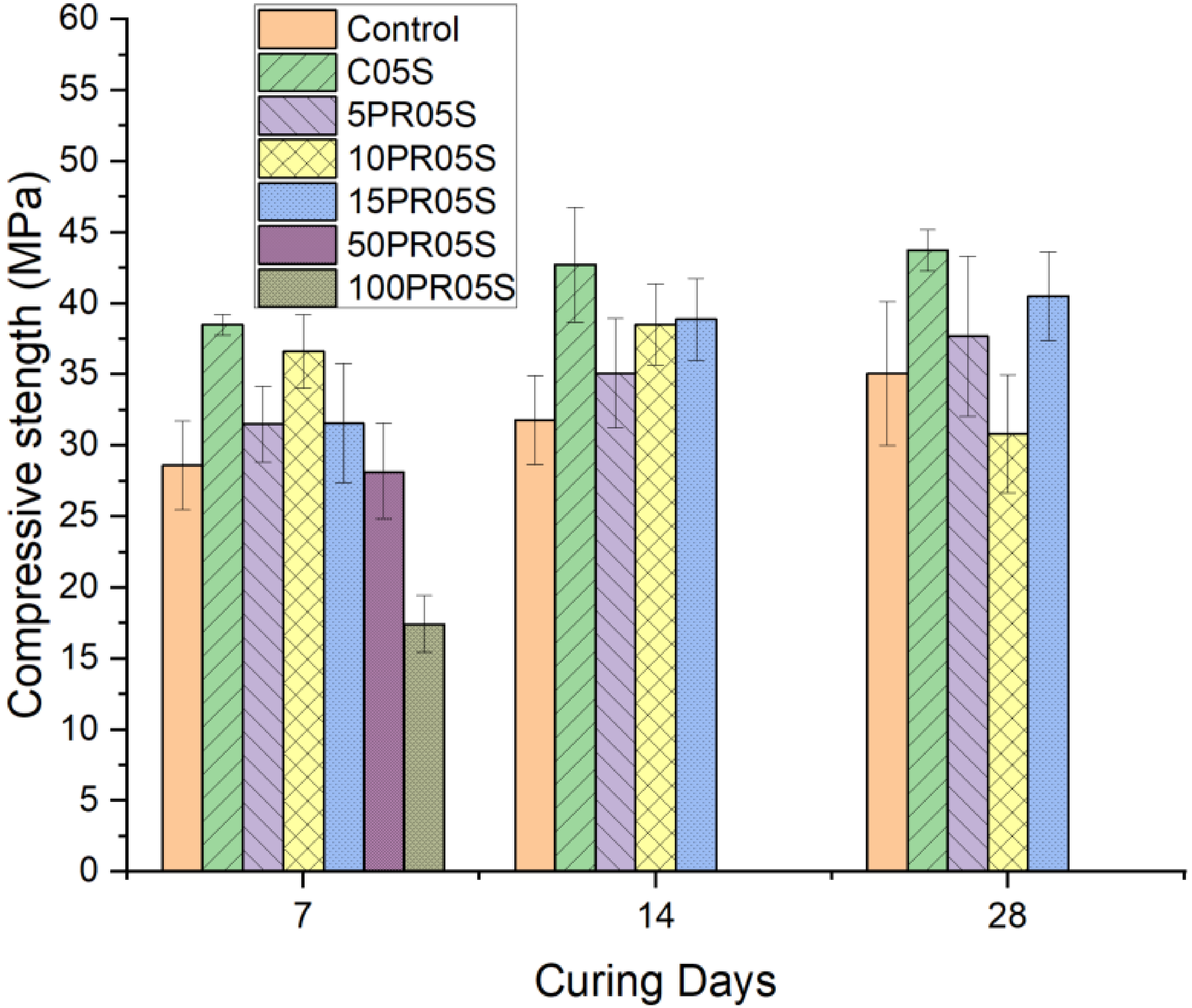


– **Low** PR replacement contents (5, 10, 15) can not **affect much of** PRM's compressive strength

– **High** PR replacement contents (50, 100) can **reduce** more compressive strength

Mechanical properties evaluation

- Compressive strength

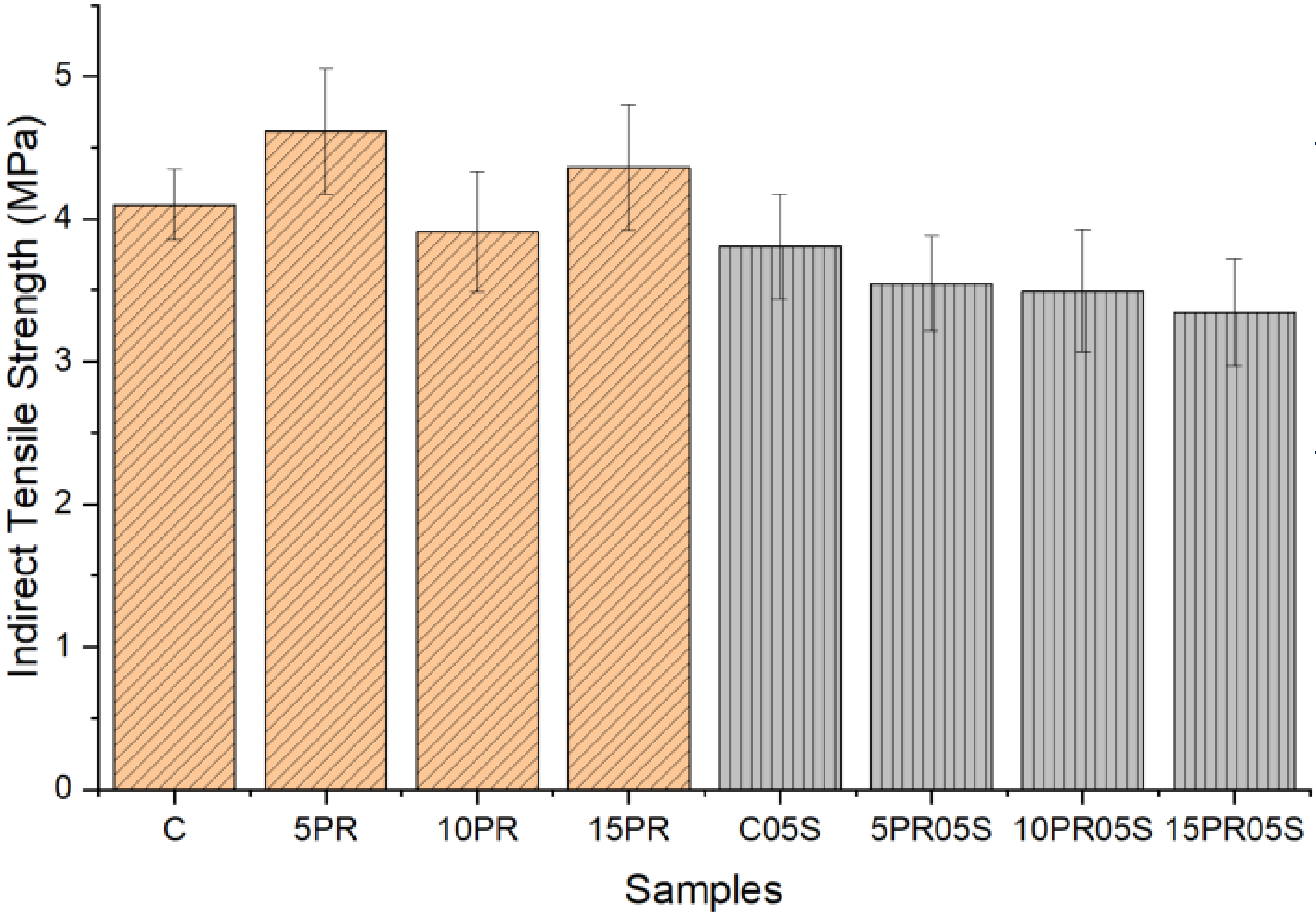


– The added steel fiber can **increase** the compressive strength compared with Control group samples

– The replaced PR reduced compressive strength by comparing with recycled steel fiber reinforced control samples

Mechanical properties evaluation

- Splitting tensile strength(28 days)

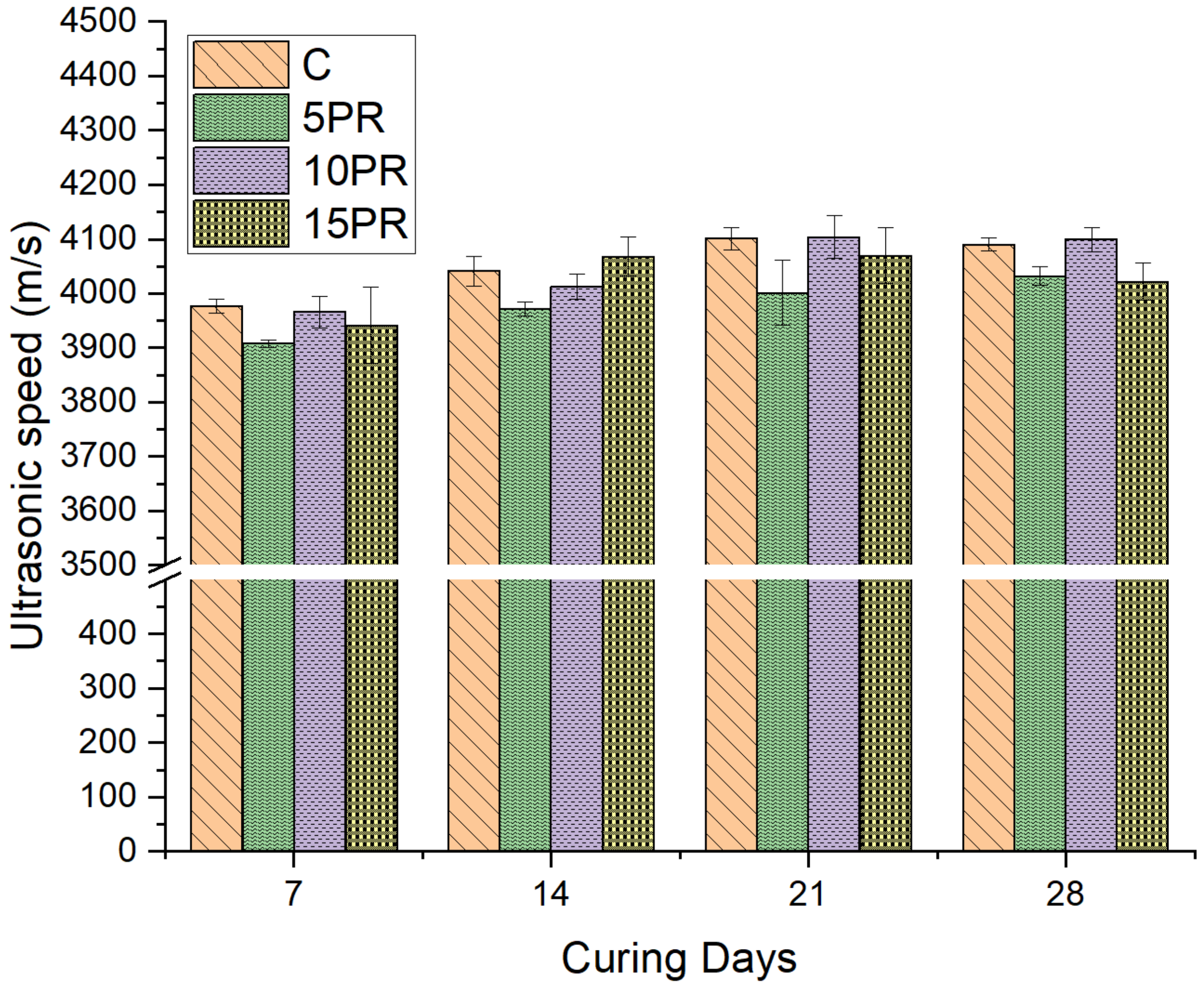


– The PRM samples (with 5 and 15 content) can increase the indirect tensile strength by comparing with Control samples.

– The added recycled steel fibers slight **reduced** the indirect tensile strength due to low interface bonding

Mechanical properties evaluation

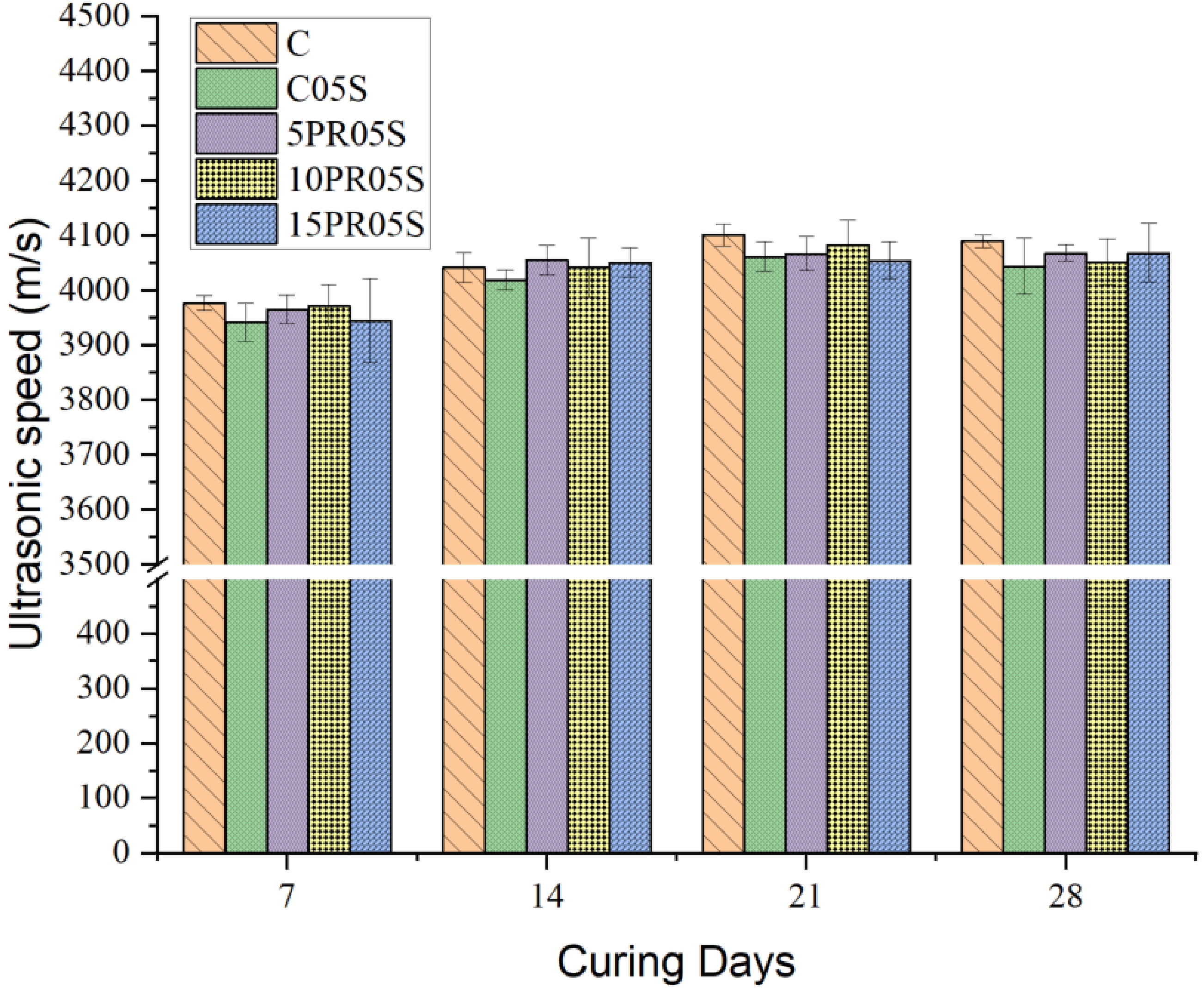
- Ultrasonic Pulse Velocity (UPV)



- The 5PR and 15PR samples have lightly lower dynamic modulus compared with control samples
- The 10PR specimens showed the highest UPV at 28 Day, which is consistent with the compressive strength test results

Mechanical properties evaluation

- Ultrasonic Pulse Velocity (UPV)



– The added Steel fiber can alleviate the reduce of stiffness caused by PR, specially for the PRM sample groups (PR5 and PR15)

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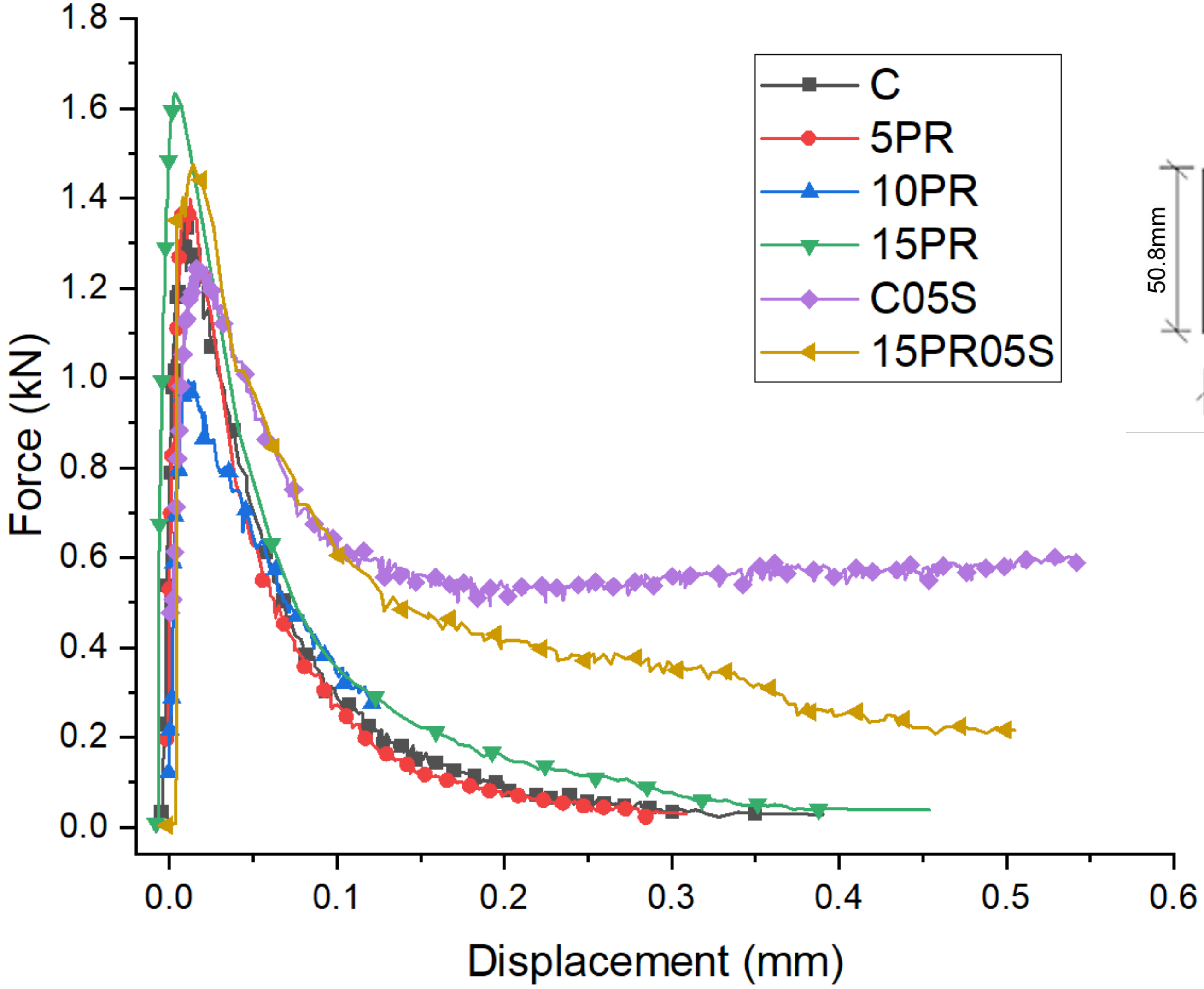
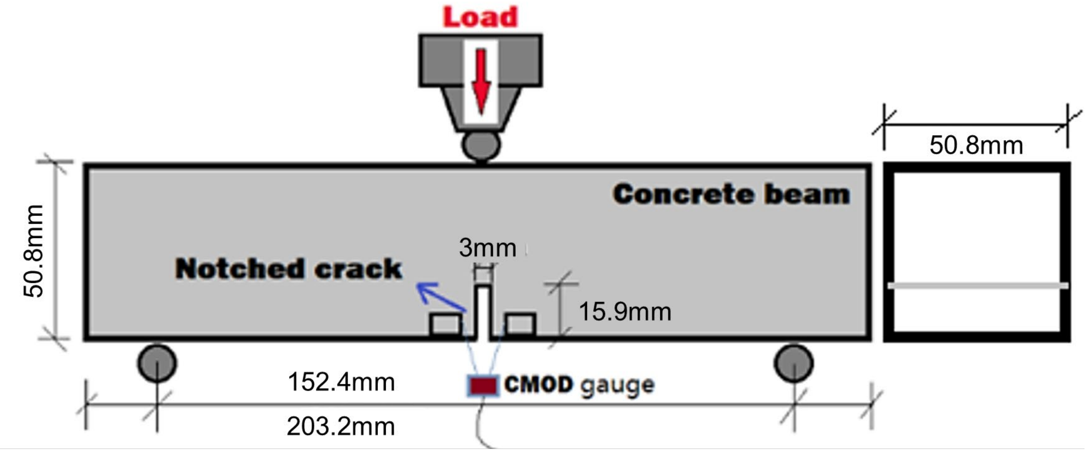
Effects of added steel fiber and different rubber contents on the fracture properties

- Flexural-fracture test results of **beam samples (50.8*50.8*203.2 mm, notch to depth ratio=0.3125)**

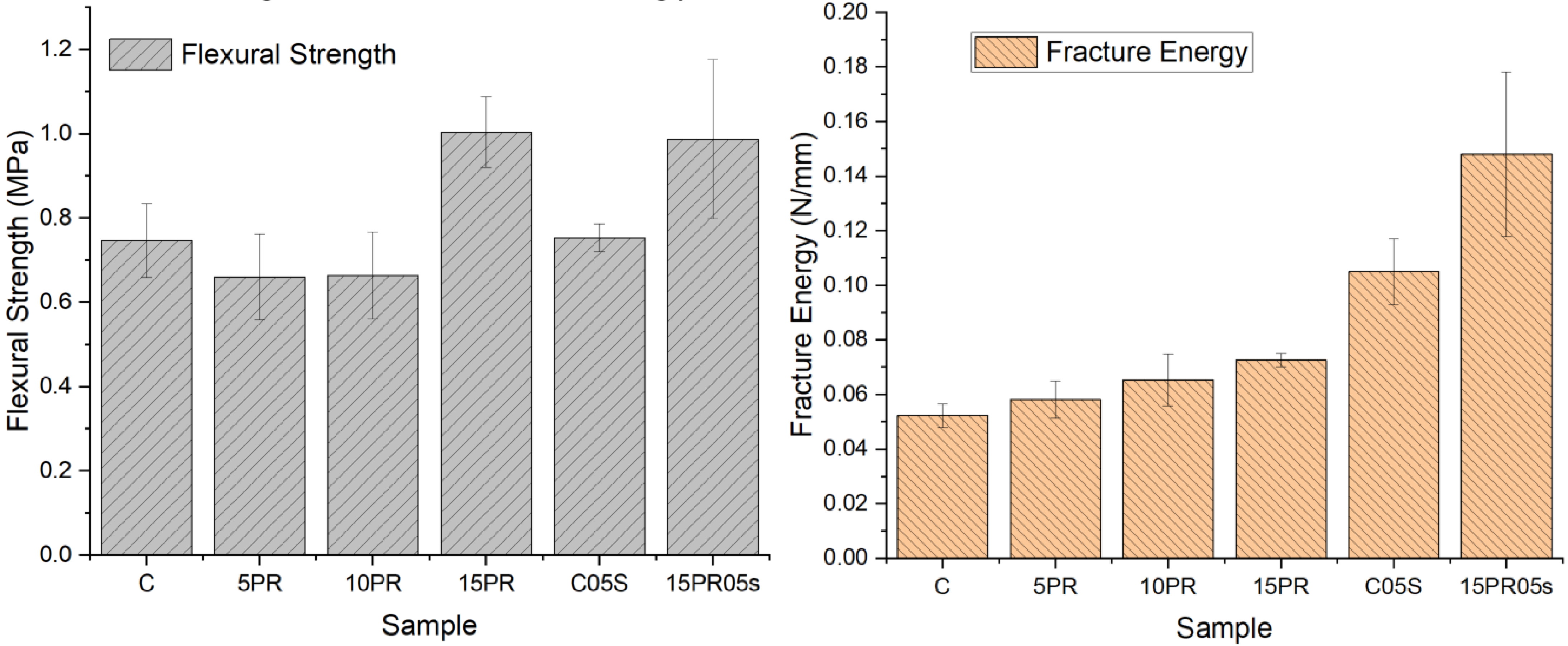




– "PRM" with steel fiber can considerably enhance the post-peak residue strength

Effects of added steel fiber and different rubber contents on the fracture properties

- Flexural strength and fracture energy



– The 15% content of PR resulted in an obvious improvement in the flexural strength

– The addition of "PR" and "Steel Fiber" can considerably improve fracture energy

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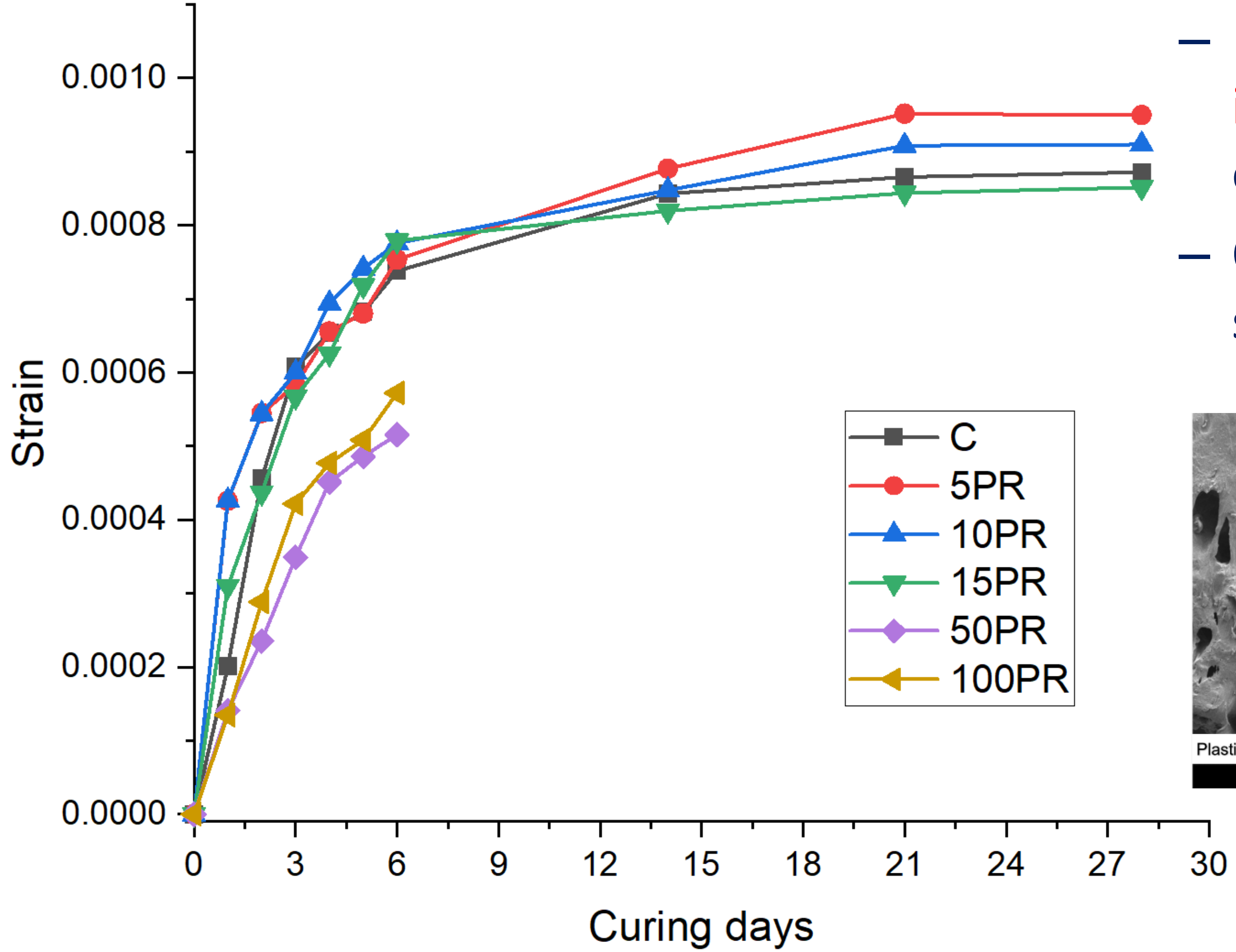
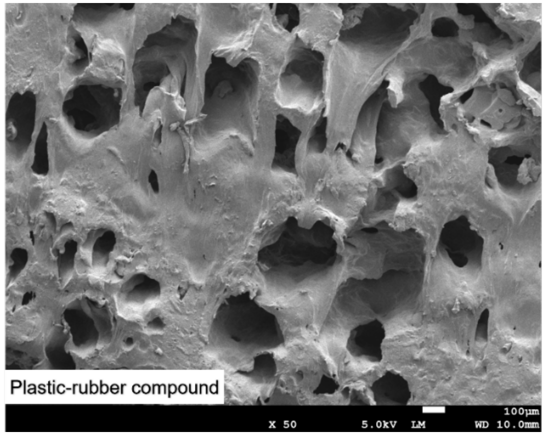
Shrinkage measurement

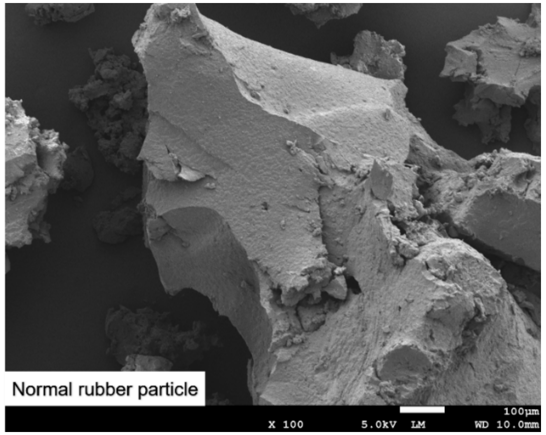
- Strain



- Different to normal rubber, the increasing of PR will not increase (or even reduce) the shrinking;
- One possible reason is that its porous structure can preserve hydration water



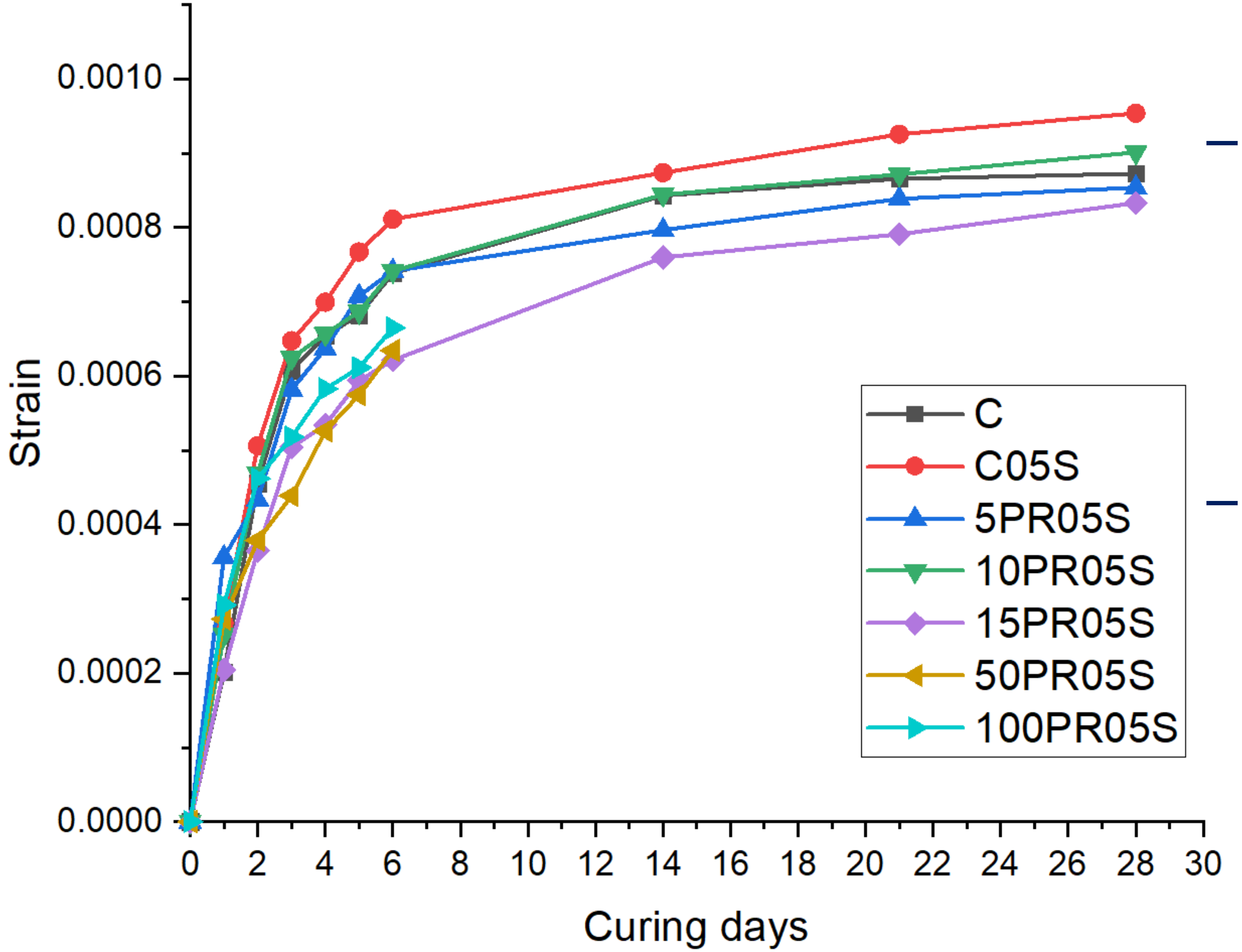
PR compound



Normal rubber

Shrinkage measurement

- Strain



- Compared to the Control group, the added steel fibers slightly increased shrinkage deformation due to low interface bonding
- The replaced PR with porous structures can slightly reduce shrinkage deformation

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Conclusions

- Low PR replacement contents (5, 10, 15) can not affect much of PRM's compressive strength and added still fiber can slightly increase compressive strength;
- PRM samples (5,15 PR replacement contents) have higher indirect tensile strength while the still fiber slightly reduce the indirect tensile strength;
- The 5PR and 15PR PRM groups have lower dynamic modulus compared with control samples and steel fiber can alleviate this reduction effect;
- The replaced PR content has slightly increase fracture energy while the added steel fiber samples have better post-peak residue strength and thus significantly increase fracture energy;
- Adding of PR can slightly reduce the shrinking due to its porous structure that can preserve hydration water.

Acknowledgments

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Thank you for your attention!

Questions?