A brief Report on Parsa Parvanehro's Activities in FIRMITAS project in 2024-2025

I join the group in February 2024 with the aim of working on the seismic retrofit of bridge piers using innovative materials like FRC concrete. The research focuses on the durability and corrosion resistance of the bridge pier retrofit strategy to meet the requirements of resilient community development.

The seismic retrofit strategy involves removing the concrete cover of the pier in sections where damage or plastic hinges have formed. The rebars are cut and replaced with new, reduced-diameter rebars, which ensure that the plastic hinge will form in this section. The new FRC concrete cover is then cast to provide shear resistance and meet confinement requirements for the longitudinal rebars. The final step involves applying a thin layer of sealer (MAPEI brand) to minimize chloride ingress and protect the rebars from corrosion. Since another advantage of FRC concrete is its ability to prevent crack propagation and create a bridging effect between cracked surfaces, this characteristic wish to be used to delay the corrosion process. For this purpose, two bridge pier specimens already existing in the PRISMA lab at Roma Tre University have been selected. The piers will undergo cyclic loading beyond the cracking stage and accelerated corrosion tests to evaluate how the proposed strategy meets corrosion resistance criteria.

In addition to the bridge piers, two pre-stressed beams, one with FRC concrete and one with normal concrete, have been designed and prepared to study the effect of FRC concrete on corrosion progression in pre-stressed beams. A platform for applying pre-tensioning has been designed and constructed in the PRISMA lab. The steel strands are tensioned successively, and concrete is cast for both beams.

Besides the bridge piers and pre-stressed beams, a group of concrete samples has been prepared, including:

1. Six 5x5x5 cm cubic samples for compressive strength tests of the concrete.
2. Six 15x15x15 cm cubic samples for compressive strength tests of the concrete.
3. Six 5x5x25 cm prismatic specimens with a rebar in the center for performing accelerated corrosion tests on small specimens.
4. Six 15x15x55 cm prismatic specimens for bending tests and characterizing the tensile strength of FRC and normal concrete.
5. Six 15x15x110 cm prismatic specimens with two rebars on the tension side of the beam for performing accelerated corrosion tests on cracked beams.

The itemized activities that have been carried out can be summarized as follows:

1. Study of Fiber-Reinforced Concrete (FRC)

The effect of adding steel fibers to concrete (FRC concrete) has been studied through papers and guidelines, such as the fib Model Code 2010 and the Italian code. The research focuses on how tensile and compressive strength are affected by steel fibers. Constitutive laws have been thoroughly studied to enable numerical modeling of pre-stressed beams under monotonic and cyclic loads.

2. Study of Bridge Pier Retrofit Strategy with Replacing Old/Damaged Rebars

The seismic repair strategy for the pier involves replacing old or damaged rebars with newly machined rebars. The diameter and length of the machined rebars significantly impact the pier's ductility and resisting moment. The repair strategy is designed to ensure that, after retrofitting, the pier can resist lateral loads without losing strength until it meets a displacement ductility demand of 4.

3. Numerical Analysis of Bridge Piers Under Monotonic and Cyclic Loads in OpenSeesPy

A numerical model of the bridge pier has been developed in OpenSeesPy, considering the tensile behavior of FRC material. This parametric model accounts for complex phenomena, such as strain penetration (rebar slippage in the foundation). It provides various results, including crack evolution under pushover loads, ductility, and more.

4. Study of Pre-Stressed Concrete Elements

Pre-stressed concrete and the losses of pre-stressing have been extensively studied. A complex Excel file has been developed to precisely calculate the effective pre-stressing force in steel strands after accounting for losses such as shrinkage, creep, elastic shortening, and strand slip at anchorage ends. This effective pre-stressing force is essential for introducing the data into finite element models of the beams in OpenSeesPy. The Excel file also calculates the shear and resisting moment of pre-stressed beams through hand calculations to verify the numerical beam model in OpenSeesPy.

5. Preparation of 30 Innovative Saddle-Shaped FBG-Embedded Fiber Optic Sensors

The pre-stressed beams are equipped with FBG-based sensors to measure strain in steel rebars. These sensors are prepared by embedding them between tissues with epoxy resin, hardening them to match the shape of the host rebar or strand. The detailed production procedure will be described in the report. These sensors are placed on rebars and pre-stressing strands in different positions to monitor strain variation during the test.

6. Numerical Study and Design of Pre-Stressed FRC or Normal Concrete Beams in OpenSeesPy

The beam has been modeled in OpenSeesPy, and inelastic analysis has been performed under monotonic and cyclic loads. The constitutive law of FRC concrete has been well implemented in the program, enabling the extraction of crack width, pushover curves, ductility, and other important results. This model is essential for designing the beam before construction and can be used for further investigation after testing.

7. Modeling, Analyzing, and Designing Lab Structures

Several lab structures have been designed and constructed to conduct experiments, including:

- A rigid platform for applying pre-stressing load on strands.
- A steel T-frame as a rigid support for actuators to apply vertical loads on beams.
- Rigid steel supports for bending tests on prismatic specimens to characterize FRC tensile parameters.

8. Literature Review on the Effect of Cracks on Corrosion of Steel Rebars or Pre-Stressing Strands

Various papers have been reviewed to study how the presence of cracks affects the corrosion resistance of beams and piers.

9. Writing Reports and Documenting Data and Activities

A detailed report has been written and is under development to document activities, tests, designs, assumptions, and more.

10. Conclusion

Many activities have been completed for the FIRMITAS project, but it is still ongoing. The beams, piers, and specimens have been well prepared, but the testing phase is still in progress.

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