Rebuilding Ukraine

THE UNIVERSITY OF BRITISH COLUMBIA

School of Engineering

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Group: Infrastructure and Structures - K

Introduction

Due to the Russian invasion of Ukraine, the transportation infrastructure in the country was severely affected. Road pavements, being a critical component of rebuilding efforts, were the primary focus of this project. Concrete mix designs were proposed for the road pavement. To incorporate principles of sustainability, recycled concrete arising from the debris was incorporated into the mix design in varying proportions as a fine aggregate (sand) substitute. Various tests were performed to determine its performance characteristics.

The goal of this capstone project is to create a concrete mix that will be used for road infrastructure that has a high enough compressive strength to withstand military equipment and to last many years in the four different seasons in Ukraine, as well as complete research on a sensor design that will detect cracks within concrete.

Materials and Methods

The different materials required in our concrete:

- Sand
- GU Portland Cement
- Aggregate size 10mm
- Water
- Air entrained
- Recycled concrete

Equipment:

- Sieving machine to retrieve 4.75mm recycled concrete
- Concrete Drum mixer

Testing:

- Sieve (4.75mm recycled concrete)
- Slump test (consistency and workability)
- Air content test (measure air voids)
- Water absorption test (ability to absorb water)
- Compression test (7, 14, 28 days testing)

Fig. 1. Materials used in the concrete mix

Asphalt vs. Concrete

Asphalt Benefits:

- Easier to replace cracked sections
- Cheaper in most countries
- Ready to drive on almost instantly
- Flexible

Concrete Benefits:

- Longer lifespan
- Stronger
- More durable

Results

For this project, the team has used the American Concrete Institute (ACI) to determine the concrete mix. To have stronger concrete for heavy machinery, the team chose to have equal weight ratios.

Mix	Cement (kg)	Sand (kg)	Recycled concrete (kg)	Coarse Aggregate (kg)	Water (kg)	W/C ratio	Air entrainer (mL)
Control Mix	16	17	0	18	5.5	0.34	15
10% Replacement	16	15.3	1.7	18	5.5	0.34	15
20% Replacement	16	13.6	3.4	18	5.5	0.34	15
30% Replacement	16	11.9	5.1	18	5.5	0.34	15

Table 1. Material proportions

Project Overview and Achievements

Using the American Society for Testing and Materials (ASTM) and European Standards to achieve the correct testing methods. With the goal of developing a sustainable and resilient concrete mix meeting a minimum compressive strength of 30 MPa, we aligned our designs with European standards. Our mix containing 30% recycled concrete fine aggregate surpassed expectations, achieving an average 28-day strength of 49.4 MPa. This validates the structural viability of our design under real-world demands.

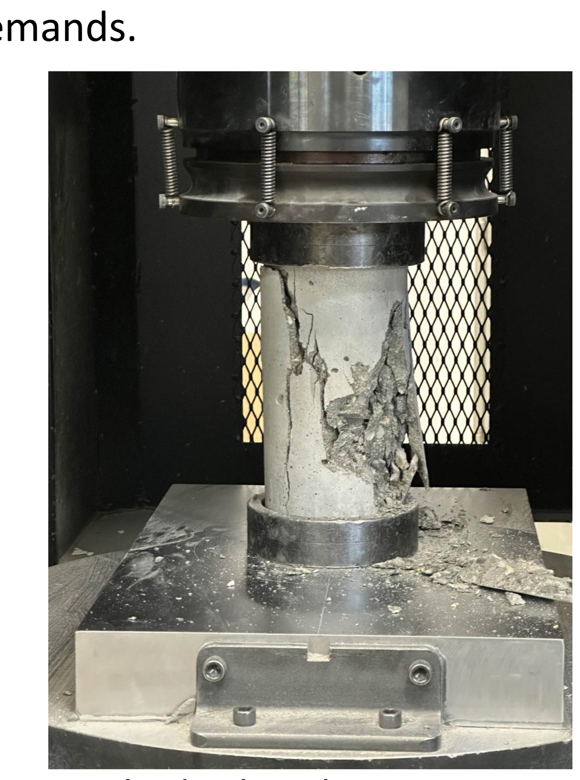

Fig. 2. Cylinder break

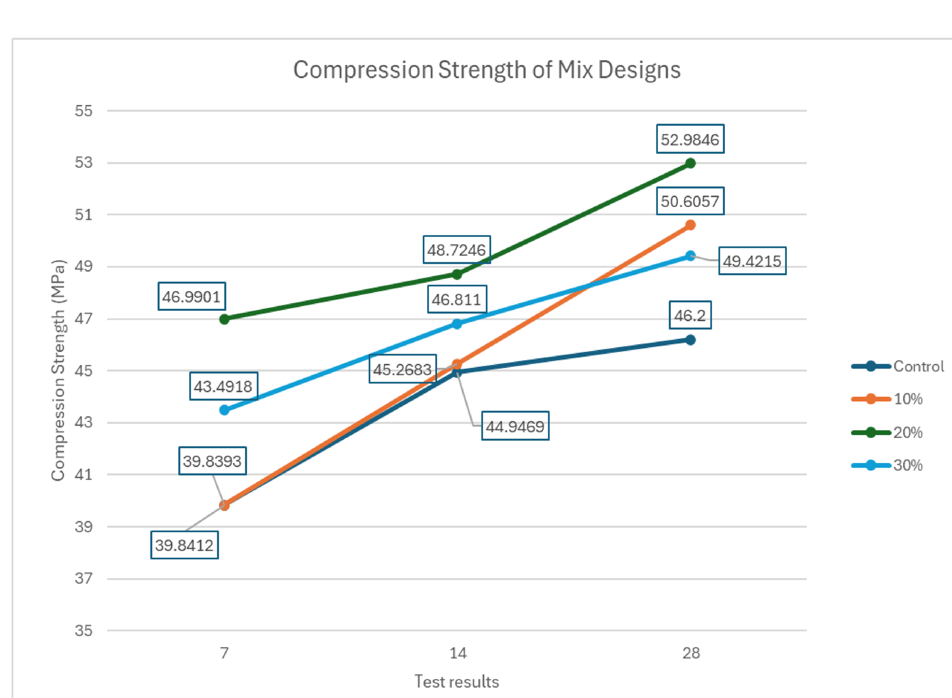

Fig 3. Compression Strengths

Fig. 3. displays the strength of the concrete mixes when tested during the 7th, 14th and 28th day. The 30% mix was chosen as our recommended concrete mix due to the significant amount of recycled concrete it contains, promoting more sustainable road construction in Ukraine while still maintaining sufficient strength for practical use.

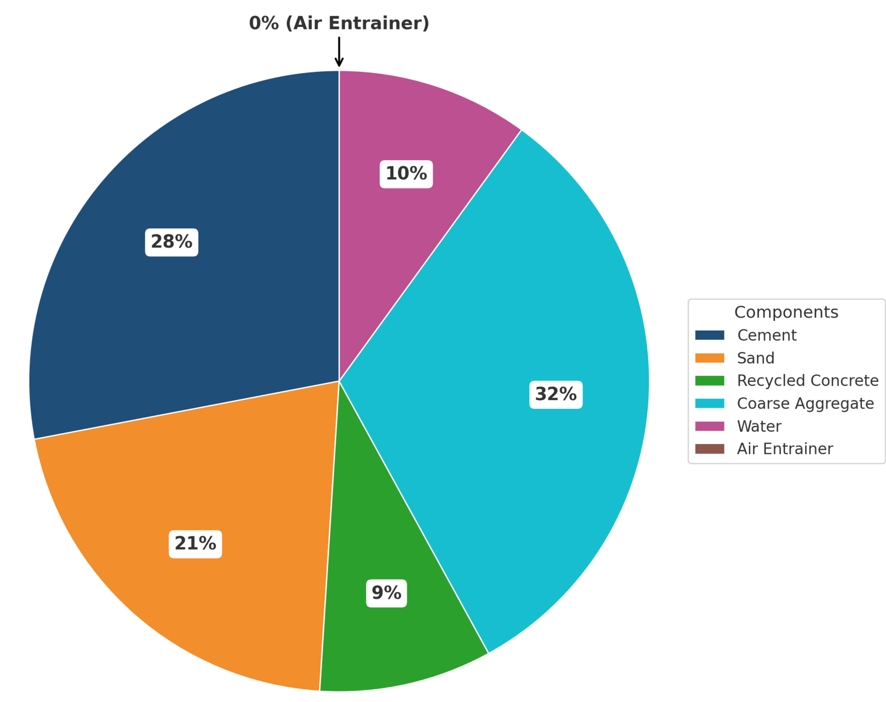

Fig. 4. Material proportion in the 30% mix

Challenges, Lessons, and Future Recommendations

Key challenges included inconsistencies in slump and air content when using recycled aggregates, and significant limitations due to equipment malfunctions — especially with fatigue testing. We learned the importance of building redundancy into testing phases and adapting quickly to material behavior.

Concrete Crack Sensor

Fig. 5. Precision 100kHz Ultrasonic Transduce

To ensure proper asset management of concrete roads, an analysis of non-destructive sensory technologies was concluded to distinguish cracks within concrete roads. As a result, a modular piezoelectric ultrasonic crack sensor was determined to be the simplest design. The design includes creating an 80V – 100kzHz – 10 cycle pulse directed to the sensor. The sensor sends an ultrasonic wave into the concrete; cracks and other distortions reflect as echoes and are picked up by the sensor and recorded for crack analysis.

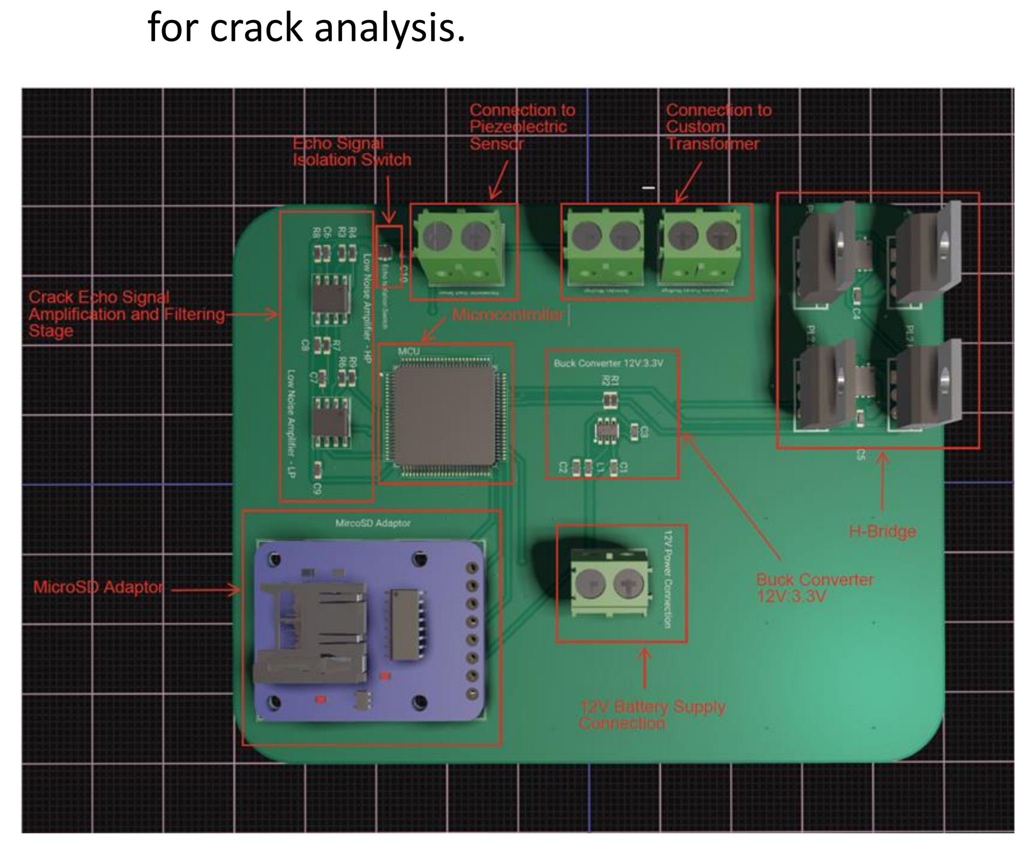

Fig. 6. Crack Sensor System overview P1

Crack Sensor Design Considerations

- Custom made transformer
- Signal Conditioning
- PCB design
- Data Collection and storage
- Crack feature analysis

Conclusions

An emphasis was placed on designing a concrete mix for road pavements able to withstand heavy military equipment and freeze-thaw cycles while incorporating waste concrete arising from the debris as one of the primary components.

Several concrete mix designs were prepared with recycled concrete in varying proportions as a fine aggregate replacement.

The 30% replacement mix was proposed as a design solution as it had a 28-day compressive strength of 49 MPa and satisfied the guidelines for concrete roads set forth by other European countries. Another important design aspect was our concrete's high slump which was necessary for practical use in Ukraine as they do not use concrete paving machines and instead use trucks and manual spreading.

Multiple UN Sustainable Development Goals were met satisfying our client's requirements.

A review of crack sensors for the purpose of structural health analysis and asset management strategies concluded in on ultrasonic crack sensor data collection unit. Initial prototype includes circuitry system requirements, MCU control code and component analysis around its operational point.

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