7. IROAST Young Internship Researchers

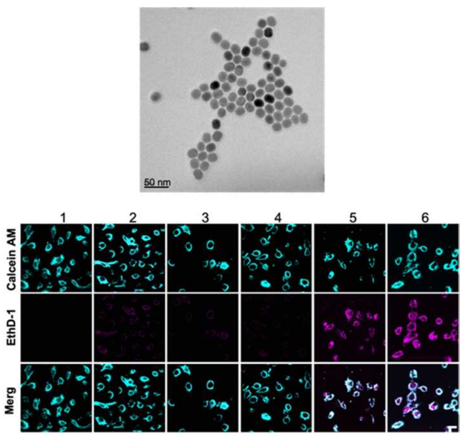
No.	Name	Project Title	Acceptance period
7-1	**Venkata Nanda Kishor Babu Adusumalli**	Multifunctional upconversion nanoparticles for imaging and treatment of Parkinson's disease	2021.09.01-2021.10.27
7-2	**Min Soo Kang**	Development of Biodegradable Drug delivery Nanoparticle based Poloxamer	2021.09.01-2021.10.27
7-3	**Woojin Lee**	Urban Planning for Lung Health in the Post-Corona Era	2021.09.01-2021.10.27
7-4	**Yue Wen**	Seismic design of resilient concrete structures under long-period ground motion	2022.01.17-2022.02.18
7-5	**Fuchao Zhao**	Seismic Design and FEM simulation of Demountable Precast RC Wall Structures	2022.01.17-2022.02.25
7-6	**Wei Liu**	The bond performance mechanism of the composite layer–original concrete interface under the main aggressive environment	2022.01.20-2022.02.18
7-7	**Yunjian He**	Bond performance between carbon fiber reinforced polymer bars and ultra-high-performance concrete	2022.01.20-2022.02.25
7-8	**Chenggong Cai**	Study on Oxygen Diffusion of Eco Concrete subjected to Loads	2022.01.31-2022.02.21

No.7-1	Multifunctional upconversion nanoparticles for imaging and treatment of Parkinson's disease		
Name	Venkata Nanda Kishor Babu Adusumalli		
Affiliation	School of Chemical Engineering, Chonnam National University, Republic of Korea Email: kishor.adusumalli8@gmail.com	Title/ Status	Postdoctoral Fellow
Research Field	Advanced Green Bio		
Period of Internship	September 1, 2021 - October 27, 2021		
Host Professor	Ruda Lee		
Affiliation	IROAST Email: aeju-lee@kumamoto-u.ac.jp	Title	Associate Professor

To use the 800 nm NIR as an excitation source, I tried to synthesize Nd^{3+}-doped upconversion nanoparticles (UCNPs) by the thermal decomposition method. To minimize non-fluorescent self-quenching between Nd^{3+} ions and lanthanides ions (e.g., Yb^{3+}, Er^{3+}), I designed core-shell structured nanoparticles. The core is Yb^{3+} and Er^{3+}-codoped $NaYF_4$ that emits green and red emission by 980 nm NIR excitation. The shell is Nd^{3+}-doped $NaYF_4$ that will absorb 800 nm NIR photons then transfer the energy into Yb^{3+} ions to activate upconversion luminescence. As a target iron (Fe^{3+})-recognizing component, the organic dye will be designed and synthesized. The organic dye will absorb 800 nm NIR light, but it will not transfer the energy to the Nd^{3+} ions resulting in no upconversion luminescence. In the presence of the target, the organic dye will transfer the energy of the absorbed NIR photons into the Nd^{3+} ions resulting in upconversion emission.

Previously, my research focused on the synthesis of UCNPs, optimization for PL efficiency improvement, and characterization of optical properties. I learned that functional nanomaterials can be applied to various biomedical applications.

Because this internship was conducted online due to COVID-19, only limited research experience is possible. Of course, regular online meetings with Prof. Lee have been very helpful to me, but if there is an opportunity in the future, I would like to utilize my nanomaterials developed in Korea to cell and animal models in Prof. Lee's laboratory in Kumamoto University.



No.7-2	Development of Biodegradable Drug delivery Nanoparticle based Poloxamer		
Name	Min Soo Kang		
Affiliation	Dept. of Anatomy, College of Veterinary Medicine, Kangwon National University Email: imkangms@kangwon.ac.kr	Title/ Status	Ph.D Candidate
Research Field	Advanced Green Bio		
Period of Internship	September 1, 2021 - October 27, 2021		
Host Professor	Ruda Lee		
Affiliation	IROAST Email: aeju-lee@kumamoto-u.ac.jp	Title	Associate Professor

Engaged Tasks During Internship periods

Date	Weeks	Engaged tasks
2021. 9. 1 ~ 2021. 9. 22	1^{st} week - 3^{rd} week	Poloxamer-PhoB synthesis, Set up NPs synthesis condition
2021. 9. 23 ~ 2021. 10. 14	4^{th} week - 6^{th} week	Ischemic cellular model imaging, western blot, real-time PCR
2021. 10. 15 ~ 2021. 10. 27	7^{th} week – 8^{th} week	NPs shipping for animal test, Figure arrangement

1. Detail activities per week

1st week: (2021. 9. 1 ~ 2021. 9. 7)

- Preparation materials for manufacturing of appropriate PLGA concentration

2nd week (2021. 9. 8 ~ 2021. 9. 15)

- preparation for manufacturing of appropriate Poloxamer-Rho B concentration
- Starting manufacturing Poloxamer-Rho B synthesis.

3rd week (2021. 9. 16 ~ 2021. 9. 22)

- Manufactured NPs synthesis under the several conditions
- The decision of suitable manufacturing condition for Poloxamer-Rho Bsynthesis,

4th week (2021. 9. 23 ~ 2021. 29)

- Confirmation of manufactured Poloxamer-Rho B NPs stability

5th ~ 6th weeks. (2021. 9. 30 ~ 2021. 10. 14)

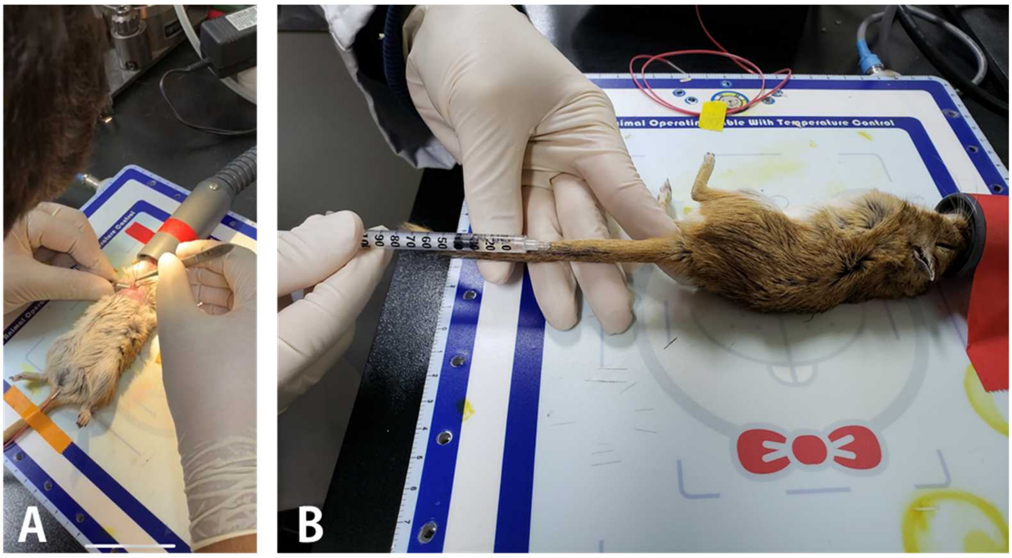
- Setup the in vitro ischemic cellular model under several conditions.
- Application of manufactured Poloxamer-Rho BNPs to analyze intracellular uptake and toxicity
- Confirmation of intracellularization of Poloxamer-Rho B NPs using fluorescent imaging.

7th week (2021. 10. 15 ~ 2021. 10. 21)

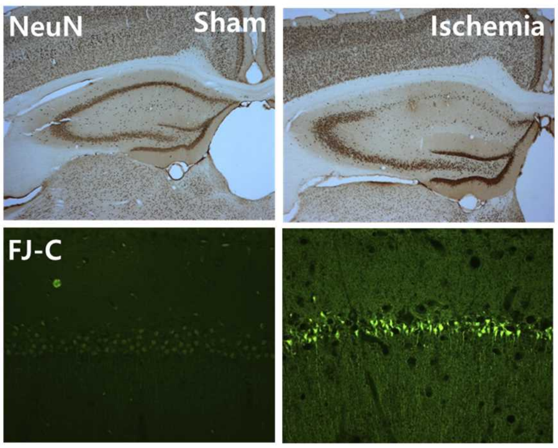
- Set up the ischemic animal models and application of Poloxamer-Rho B NPS intravenous injection via tail vein

8~9th weeks: (2021. 10. 22 ~ 2021. 10. 27)

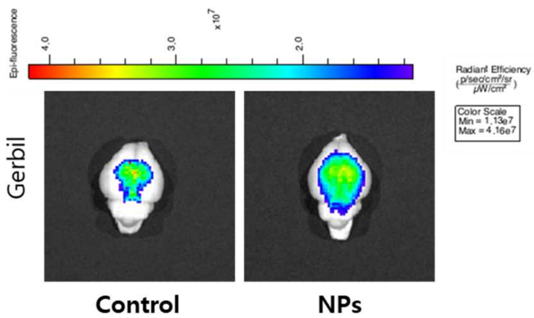
- Sacrificed animals and made cryoprotected brain tissue for analysis of distribution ischemic brain structures
- Histological analysis of toxicity on the major organs
- Preparation of IROAST Internship Program final report



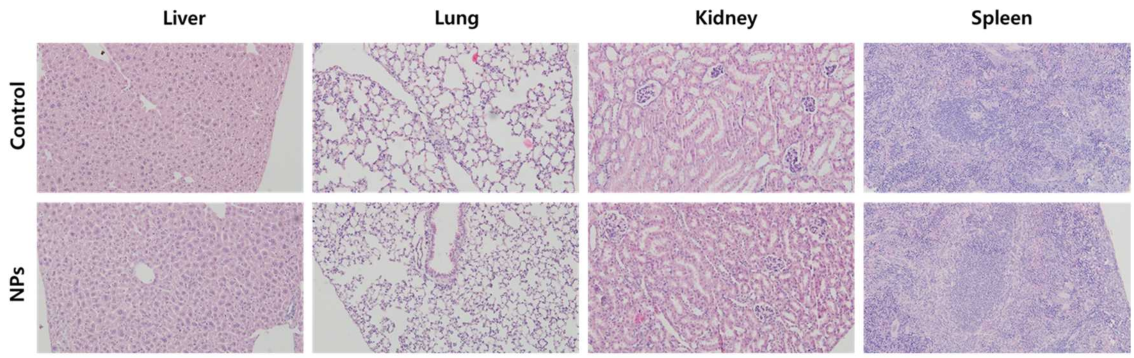
A, Induction of brain Ischemia. B, Intravenous injection via tail vein



Histological analysis of Ischemic brain



Distribution of Poloxamer-Rho B NPs in the ischemic brain



Histological toxicity analysis of Poloxamer-Rho B NPs in the ischemic gerbil model after Poloxamer-Rho B NPs injection

2. Future research plans

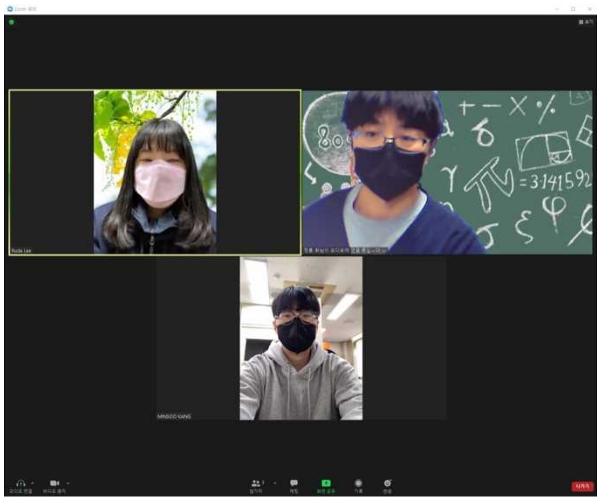
I. Further immunohistological analysis of ischemic brain

- Astroglial changes after Poloxamer-Rho B NPs injection
- Microglial changes after Poloxamer-Rho B NPs injection

II. Further development of NPs using the various size of poloxamers

III. Development of drug delivery system using the Poloxamer-Rho B NPs for protection of brain ischemic condition and therapy

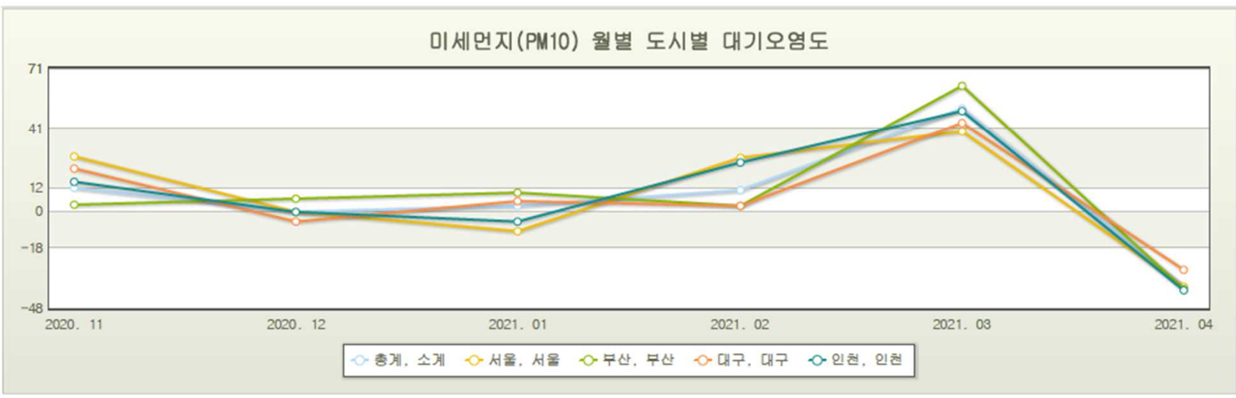
Prof. Lee and my supervisor, Prof. Choi are closely collaborating for brain disorder diseases. We have a plan to load drugs inside the Poloxamer NPs and track the therapeutic efficacy. The paper will be submitted in 2022 to the top 5% brain disease journal.



No.7-3	Urban Planning for Lung Health in the Post-Corona Era		
Name	Woojin Lee		
Affiliation	Department of Urban Convergence System Engineering, Kongju National University Email: mocksha@naver.com	Title/ Status	Research Associate (Post Doctor)
Research Field	Advanced Green Bio		
Period of Internship	September 1, 2021 - October 27, 2021		
Host Professor	Ruda Lee		
Affiliation	IROAST Email: aeju-lee@kumamoto-u.ac.jp	Title	Associate Professor

For selecting the research era, I searched the Korea Statistical Office website. As a result, I found that Janseong city has the largest Hinoki forest in Korea. We already know that phytoncide is good for mental health and anti-bacteria. However, there is no research on the benefit of urban forest in post-corona. We performed big data analysis as well as got scientific prove for enhancing research quality.

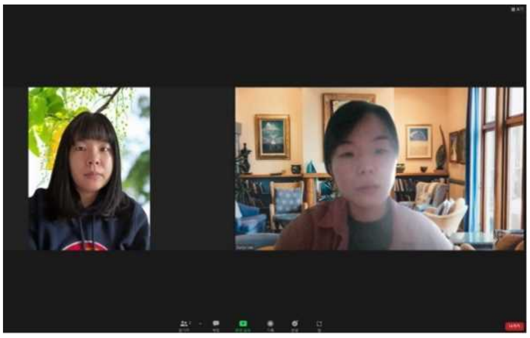
The largest Chamaecyparis obtusa (hinoki) area in Korea



Monthly fine dust changes in the big cities at Korea

As my research field is far from Prof. Lee's field, it was hard to understand each other. For example, the research size was big differences. Prof. Lee's research is focused on small-size materials, meanwhile, I am concerning the national scale. In the beginning, we thought of different directions for the subject. During the internship period, we had a zoom meeting every week and keep closely discussing the project. Finally, we decide the most proper area in Korea and start to search the relation between urban forest and lung health. For that, I and an Otolaryngologist analyze big data from Korea Statistical Office. It was a good chance to understand different research fields and perform real interdisciplinary research.

In the present, environmental issues are important all around the world. So, interdisciplinary research collaboration is mandatory. I will stay at University as an Assistant Professor. I took the first step with Prof. Lee. This research will be an example of medicine and environmental engineering can make synergy for Well-Being Society.



No.7-4	Seismic design of resilient concrete structures under long-period ground motion		
Name	Yue Wen		
Affiliation	Nanjing University of Science and Technology Email: 2575376822@qq.com	Title/ Status	Graduate Student
Research Field	Environmental Science		
Period of Internship	January 17, 2022-February 18, 2022		
Host Professor	Gaochuang Cai		
Affiliation	IROAST Email: cai@kumamoto-u.ac.jp	Title	Associate Professor

1. Research Background

Nowadays, earthquakes are more and more frequent, for instance, the 1995 Kobe earthquake, the 2008 Sichuan earthquake, and the 2011 Eastern Japan earthquake [1,2]. The most important thing in the structural seismic design is that the structural system must contain sufficient ductility and energy-absorption capacity to withstand large seismic forces [3]. As very commonly used seismic structures, reinforced concrete (RC) structures are widely used in Japan. To ensure that these structures have sufficient seismic capacity, ductile RC structures have been widely accepted in the past 40-50 years. Because such a structure can usually resist earthquakes effectively, ensuring that the structures do not collapse during the earthquake. However, recent research trends show that not only the collapse resistance of the structures is concerned, but the repairability of the structures at post-earthquake is also important. This is because it involves the post-earthquake restoration of the structure and the reconstruction of the earthquake-affected area, not only in terms of time but also in terms of cost.

However, in the post-earthquake field surveys of the major earthquakes, I mentioned above, many RC structures have large residual deformations after the earthquakes. These will not only increase the maintenance and repairing cost of the building, but also make it more difficult to obtain faster disaster restoration and reconstruction. After a strong earthquake, because the damage is unpredictable [4], how to repair the building structures is also a big problem, usually, such a structure will be demolished. This causes a waste of resources. Therefore, as for structural seismic design, the research trends are to make the buildings maintain serviceability without large residual deformations even after being subjected to strong earthquakes.

2. Tasks of the internship

We began this internship on 2022/01/21, there is a kickoff meeting to explain the details of the program.

In the first week, I did the literature investigation on resilient concrete structures, which is to outline the review, understand the key to the resilience of RC structure and understand the concepts of resilient concrete, seismic and stress-hardening.

Then in the second week, I did the literature review of how to control the residual displacement of the structures at post-earthquake, which is mainly to summarize the methods to control the residual displacement-stressing technology, de-bonding tech, and low-bond-high strength steel rebars.

After that, in the third and fourth weeks, I investigated the current research results and comment on the technologies to assess the methods and comparison analysis.

3. Results

3.1 Outline of the literature review

The structure will be as follows:

1. Introduction

Current technology

- self-centering capability /drift hardening
- previous research overview

2. Reinforcements

2.1 PC technology and PT tendons

2.2 De-bonding of steel reinforcement

(1) complete de-bonding

(2) partly DB

2.3 FRP rebars

2.4 Self-centering reinforcement

2.5 High-performance materials-SMA reinforcement

2.6 Hybrid approach

3. Concrete (only control the damage, possible)

4. External confinement and resistance

5. Others

3.2 Methods to control the residual displacement of the structures

Pre-stressing technology

3.2.1 Cast-in-place concrete approach

3.2.2

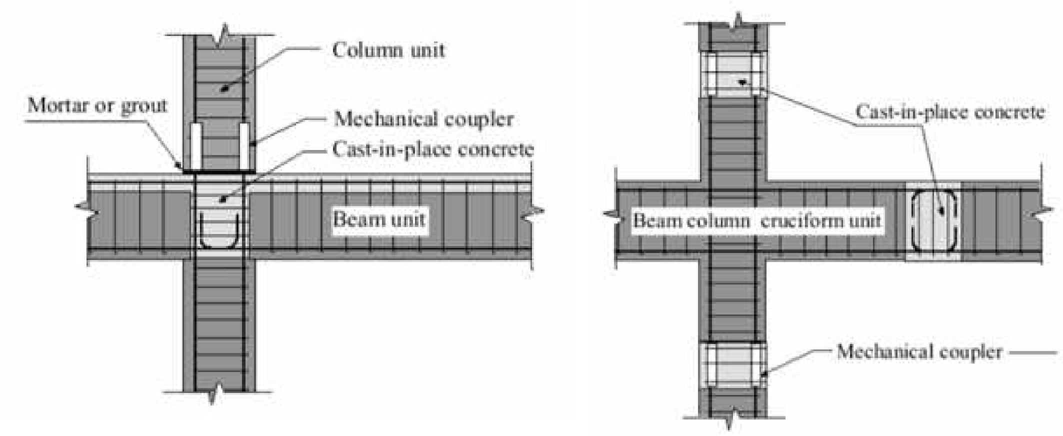


Fig 3-1 Cast-in-place concrete approach

3.2.3 Jointed ductile and hybrid systems

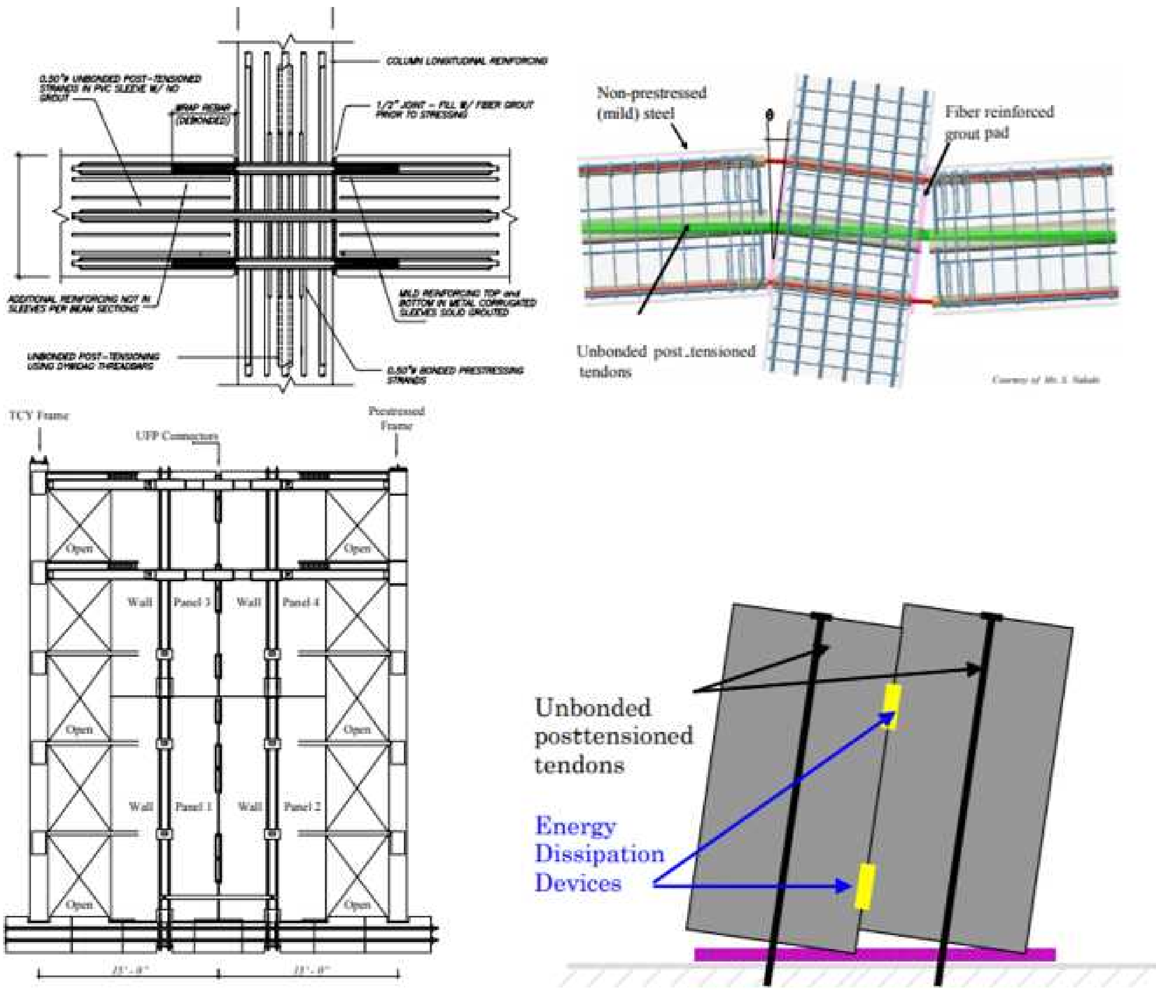


Fig3-2 Jointed ductile and hybrid systems

De-bonding tech

Bonding is a preferred method compared to drilling process steps for riveting or screwing since it allows the transfer of forces during load without degrading the fibers.

Advantages	Disadvantages
Load distribution	Temperature limit
Bonding of fragile materials	Ageing
Bonding of materials of different kind	Reliability
Bonding of thin materials	Sensibility to the environment depending of the type of adhesive
High resistance	
Retains shape	Surface pre-treatment
Flexibility of conception	Price?
Reduction of the number of pieces	Time of preparation
Water tightness / air tightness	Non destructive tests
Aesthetic	Separation of the parts for repair, rework or recycling
Vibration absorption	
Protection against corrosion	
Electric and thermal insulation	

Three main ways can be combined to modify the bonding joint in order to obtain a debonding property. The first way is to modify the interface substrate/adhesive. The second way is to modify the chemical structure of the adhesive, so that after a trigger, mostly temperature, the crosslinking step is "reversed". The last method is to add in the adhesive reactive fillers that will attack or destroy the adhesive after triggered activation.

3.3 Current research results on the technologies

3.3.1 Motivation of High-Performance DRSRS Systems

For the sake of protecting the lives of the occupants, structures are typically designed for “life-safety” performance according to the most modern building codes and are expected to undergo significant structural or nonstructural damage referred to as residual deformation during a severe earthquake.

3.3.2 Basic Principles and Methodology of High-Performance DRSRS Systems

The conventional seismic resisting structural system undertakes two responsibilities simultaneously

3.3.2.1 resisting the earthquake force through strong stiffness (energy dissipation devices)

3.3.2.2 dissipating the earthquake energy through inelastic buckling or yielding of longitudinal bars and crushing of concrete at compression zone (base isolation)

3.3.3 Replaceable Structural Elements

3.3.3.1 Bridge Engineering Structure

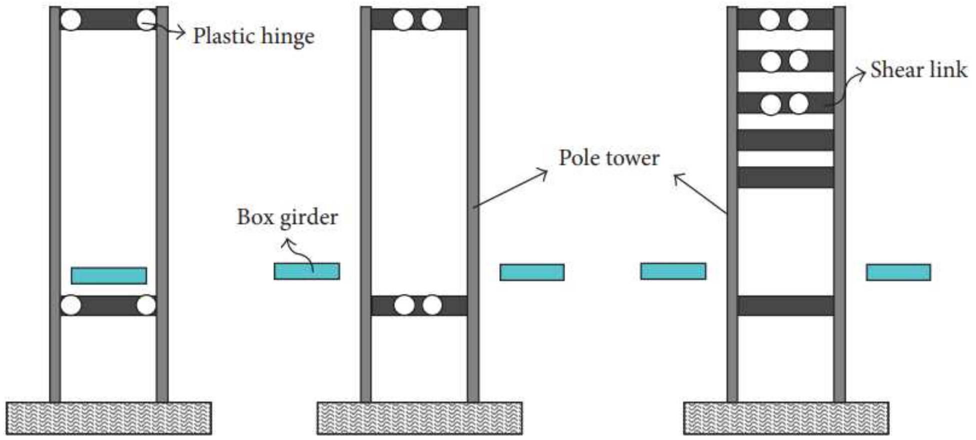


Fig3-3 Bridge Engineering Structure

3.3.4 Coupling Beam of Shear Wall System

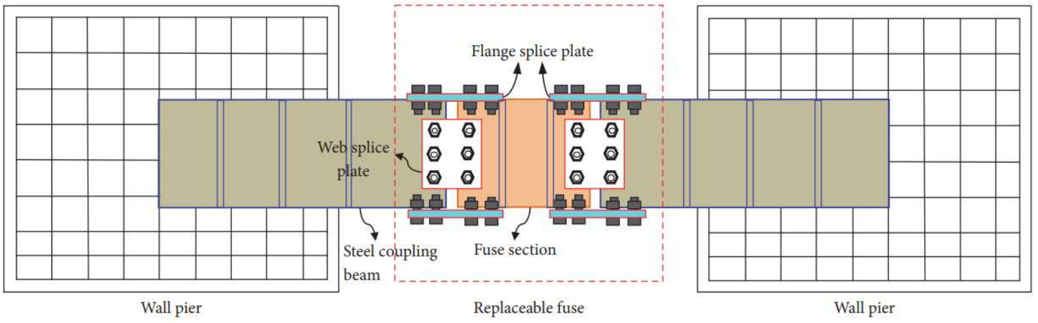


Fig3-4 Coupling Beam of Shear Wall System

3.3.5 Frame Structural System

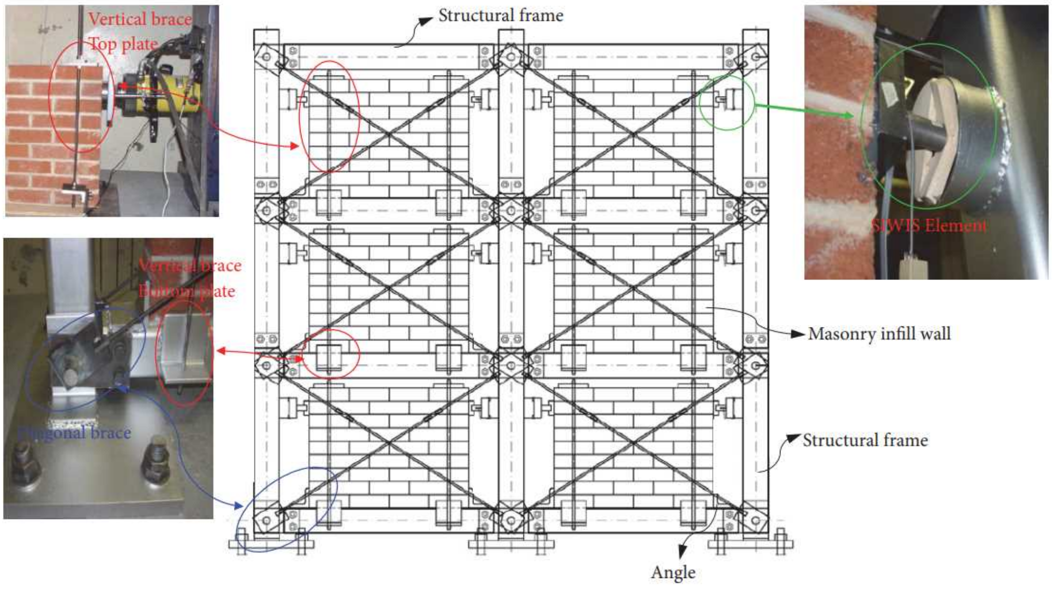


Fig3-5 Frame Structural System

3.3.6 Rocking Seismic Resisting Structural Systems

1. Rocking Bridge Pier Structure
2. Rocking Concrete Frame System
3. Rocking Steel Frame System
4. Rocking Concrete Shear Wall System
5. Rocking Masonry Structural Wall System

3.3.7 Self-Centering Seismic Resisting Structural Systems

3.3.7.1Self-Centering RC Frame System

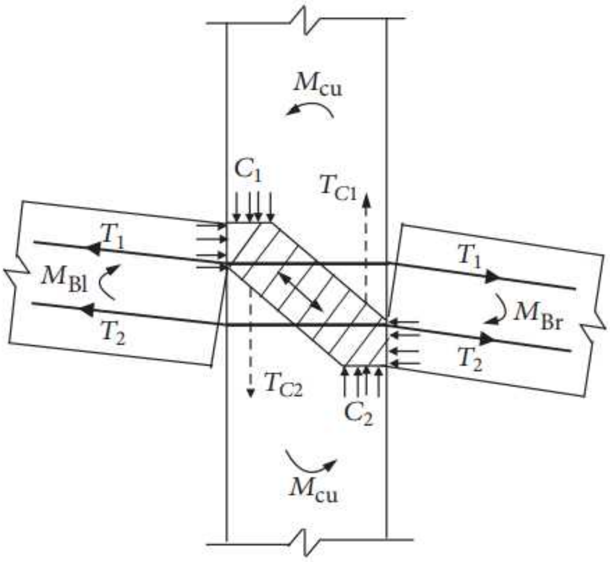


Fig3-6 Self-Centering RC Frame System

3.3.7.2 Self-Centering RC Shear Wall System

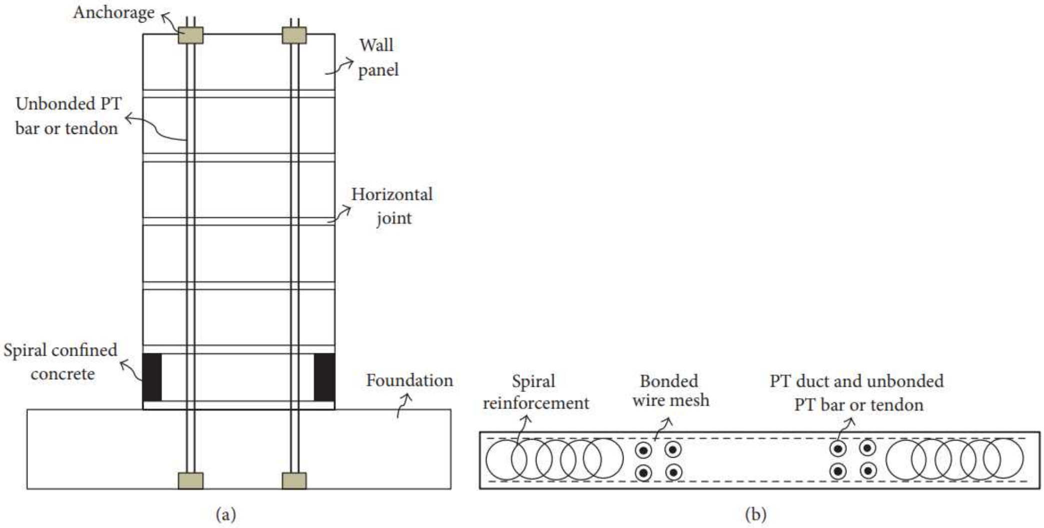


Fig3-7 Self-Centering RC Shear Wall System

3.3.7.3Self-Centering Steel Frame System

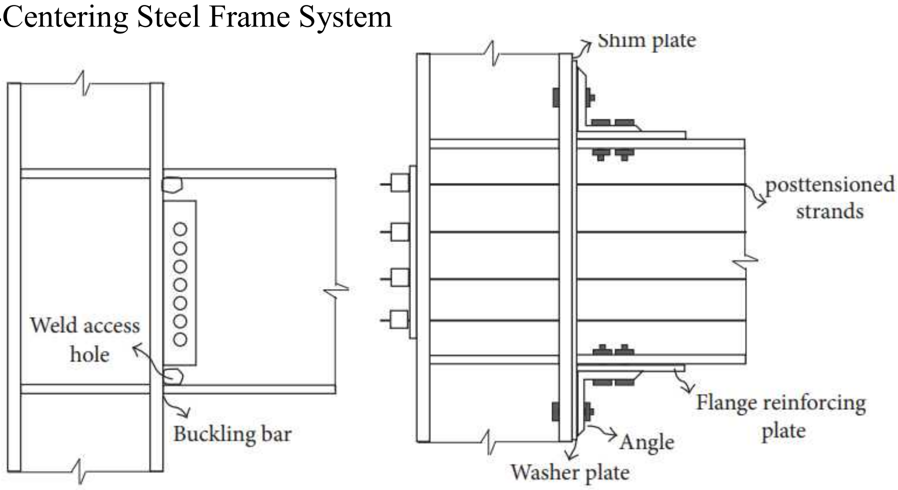


Fig3-8 Self-Centering Steel Frame System

3.3.7.4 Self-Centering Masonry Structural Wall System
3.3.7.5 Self-Centering Timber Structural System
3.3.7.6 Self-Centering Bridge Pier Structural System

3.3.8 Analysis and Design Seismic Behavior of DRSRS System

3.3.9 Current Research Challenges in High-Performance DRSRS Systems

4. Achievement

A literature review paper will be submitted to the Journal of Building Engineering (Q1, IF 5.318) based on this internship, which will be entitled "Self-centering concrete structures-the state of the art".

5. Future Research Plan

Firstly, the paper of the literature review will be published in June this year based on the tasks which have been engaged in during this internship.

Then after that, I will do a series of experiments at Kumamoto University about resilient concrete structures. The material and structure experiments will be conducted under multiple cyclic loads, and the constitutive models will also be established.

After that, based on the constitutive models the finite elements will be established. The time-history analysis of structures will be conducted.

According to all the research, two purposes will be achieved. The first one is to develop a resilient structure of concrete columns with ultra-high-strength materials. The second one is to optimize the structural design and member usage.

Reference

1]. Takeuchi, T., Sun, Y., Tani, M., & Shing, P. S. B. (2021). Seismic Performance of Concrete Columns Reinforced with Weakly Bonded Ultrahigh-Strength Longitudinal Bars. *Journal of Structural Engineering*, *147*(1), 04020290.

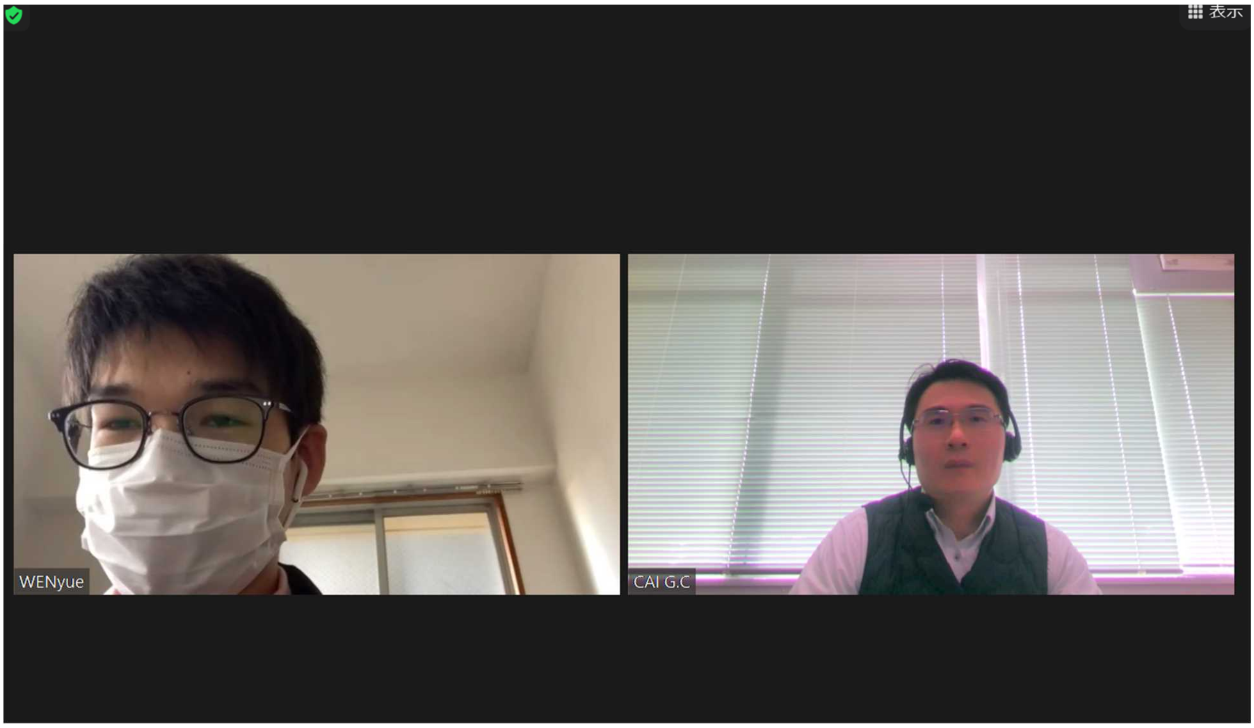
[2]. J.H. Wanga, Y.P. Sunb, d, T. Takeuchib, T. Koyama, d. Seismic behavior of circular fly ash concrete columns reinforced with low bond high-strength steel rebar. Structures 27 (2020) 1335–1357.

[3].Hegger, J., Will, N., Bruckermann, O., & Voss, S. (2006). Load–bearing behaviors and simulation of textile reinforced concrete. Materials and structures, 39(8), 765-776.

[4]. Shams, A., Stark, A., Hogan, F., Hegger, J., & Schneider, H. (2015). Innovative sandwich structures made of high-performance concrete and foamed polyurethane. Composite Structures, 121, 271-279.

Appendix

The following photos show what the internship looked like at that time.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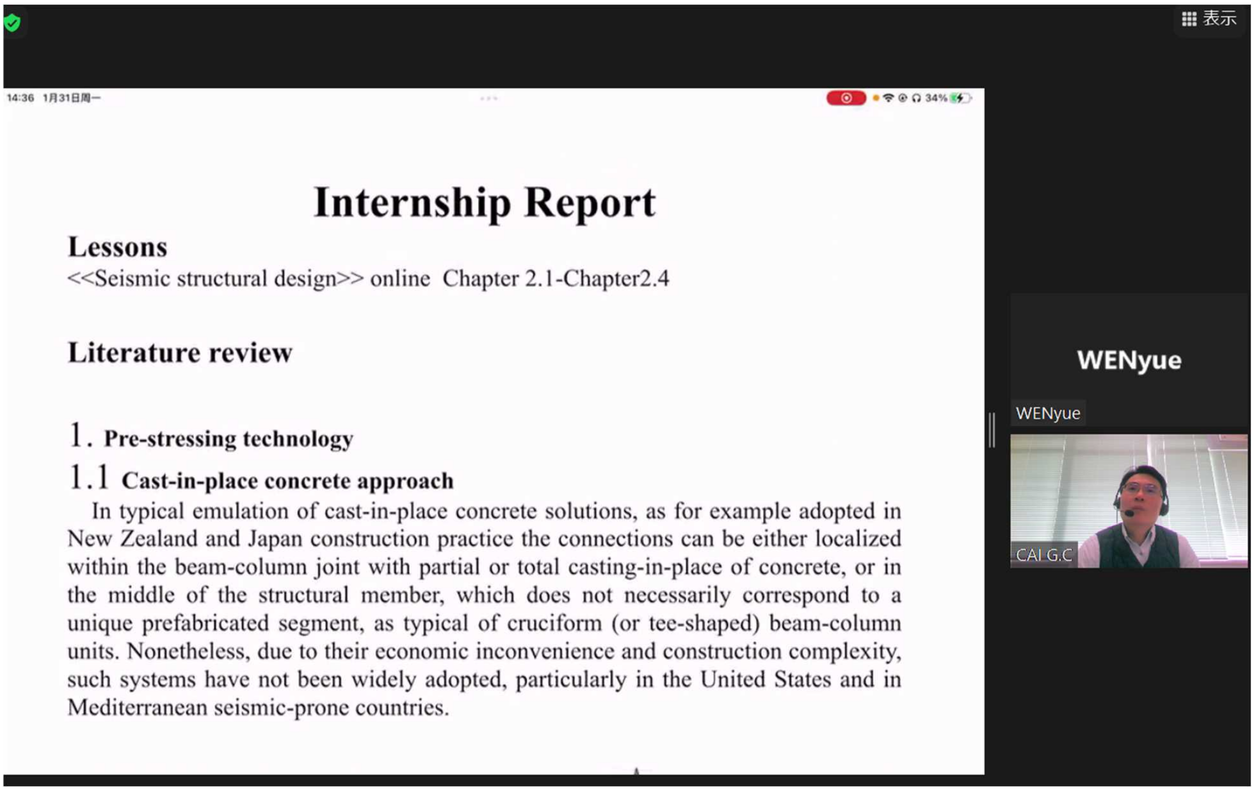
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Internship Report
Lessons
<<Seismic structural design>> online Chapter 2.1-Chapter2.4
Literature review
1. Pre-stressing technology
1.1 Cast-in-place concrete approach
In typical emulation of cast-in-place concrete solutions, as for example adopted in New Zealand and Japan construction practice the connections can be either localized within the beam-column joint with partial or total casting-in-place of concrete, or in the middle of the structural member, which does not necessarily correspond to a unique prefabricated segment, as typical of cruciform (or tee-shaped) beam-column units. Nonetheless, due to their economic inconvenience and construction complexity, such systems have not been widely adopted, particularly in the United States and in Mediterranean seismic-prone countries.
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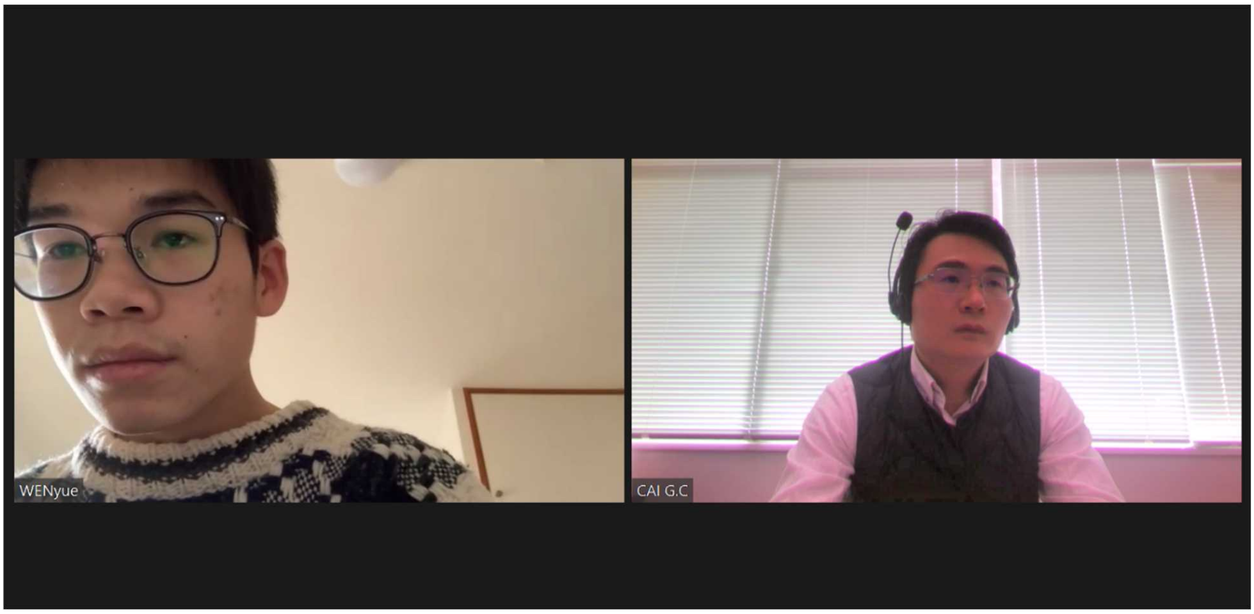
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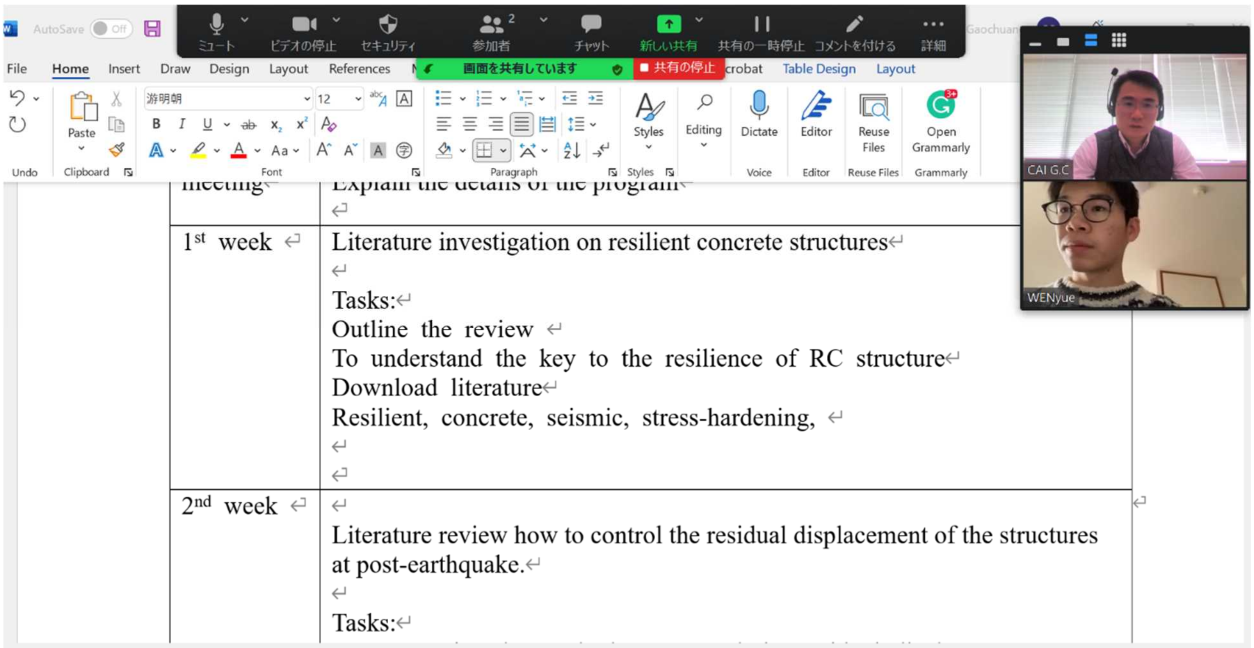
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1st week
Literature investigation on resilient concrete structures
Tasks:
Outline the review
To understand the key to the resilience of RC structure
Download literature
Resilient, concrete, seismic, stress-hardening,
2nd week
Literature review how to control the residual displacement of the structures at post-earthquake.
Tasks:
CAI G.C
WENyue

No.7-5	Seismic Design and FEM simulation of Demountable Precast RC Wall Structures		
Name	Fuchao Zhao		
Affiliation	University of Lyon Email: fuchao.zhao@foxmail.com	Title/ Status	Visiting Ph.D. Researcher
Research Field	Disaster prevention and mitigation		
Period of Internship	January 17, 2022-February 25, 2022		
Host Professor	Gaochuang Cai		
Affiliation	IROAST, Kumamoto University Email: cai@kumamoto-u.ac.jp	Title	Associate Professors

Research background and objectives

Most Reinforced concrete (RC) structures are constructed using the conventional monolithic casting method. When the structure ends its life span for damaged by load effects or degraded for environmental impacts, it has to be demolished. This process usually wastes a lot of valuable materials. Structure with a dry connection hardly requires post-casting. Through dry connection, the precast concrete (PC) structures are easy to assemble quickly and the structural components are demounted and reused to extend their lifespan.

Considering the unique structural characteristics of dry connection, the design method is different from the conventional design method of monolithic casting structure. However, there is a lack of the overall seismic design theory based on dry connection. Meanwhile, the research on the influence of the deformation of the connection on the structural performance is relatively less. It is vital to research the seismic behavior and the design method of the demountable PC wall panel.

The main tasks are as follows:

- Clarifying the damage mechanism, failure mode, force-transfer mechanism, and energy dissipation performance of demountable PC wall panel building system.
- Investigating the influence of the deformation of joints on the drift of the overall structure.
- Develop the calculation methods for predicting the shear capacity of the wall panels with bolted connections.

Experimental investigation

A lightweight precast panel building system with simple bolted connections was proposed, as shown in Fig.1. The application of lightweight concrete is expected to be easy to manufacture and transport which can significantly improve construction efficiency.

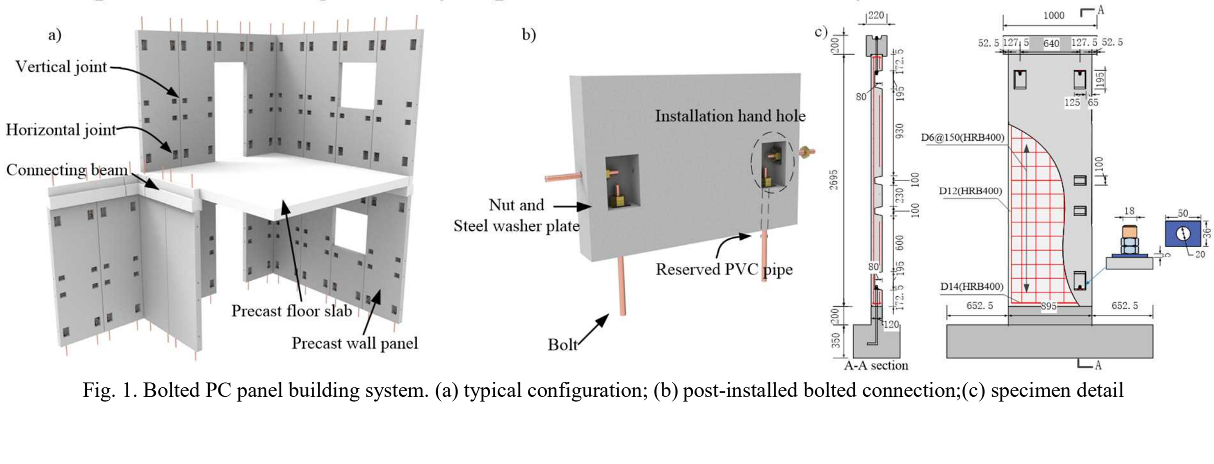


Fig. 1. Bolted PC panel building system. (a) typical configuration; (b) post-installed bolted connection;(c) specimen detail

To analyze the seismic performances of the bolted connection wall panel, three full-scale specimens with different axial loads and concrete compressive strength were designed and tested by a quasi-static cyclic load. In general, all the bolted panels presented significant lateral deformability and failed with a concrete crushing with several flexural and flexural-shear cracks around the tension bolts. The failure of the joints is mainly attributed to the yield of the bolts with several flexural-shear cracks surrounding them. For the deformation performance, the top horizontal displacement of the specimens could be divided into (1) flexural and shear deformation displacement of the wall panel and (2) the slippage and (3) the rotational displacement of the horizontal joints. And the rotational deformation caused by the distortion of steel bolts was prevalent, and it often accounts for a large proportion of overall lateral displacement.

Finite element analysis

The FEA models of the PC wall panels (Fig.2) were established by using commercial software, ABAQUS. The concrete damaged plasticity model was used to model concrete behavior, which assumed that there was no associated potential flow rule and used the yield surface to illustrate the different evolution of strength under tension and compression. In the FEA models, a surface-to-surface interaction occurs between connecting beam-PC wall, between PC wall-foundation beam, and between plate-concrete, respectively. The displacement-controlled loading process was carried out by using the dynamic implicit method in ABAQUS.

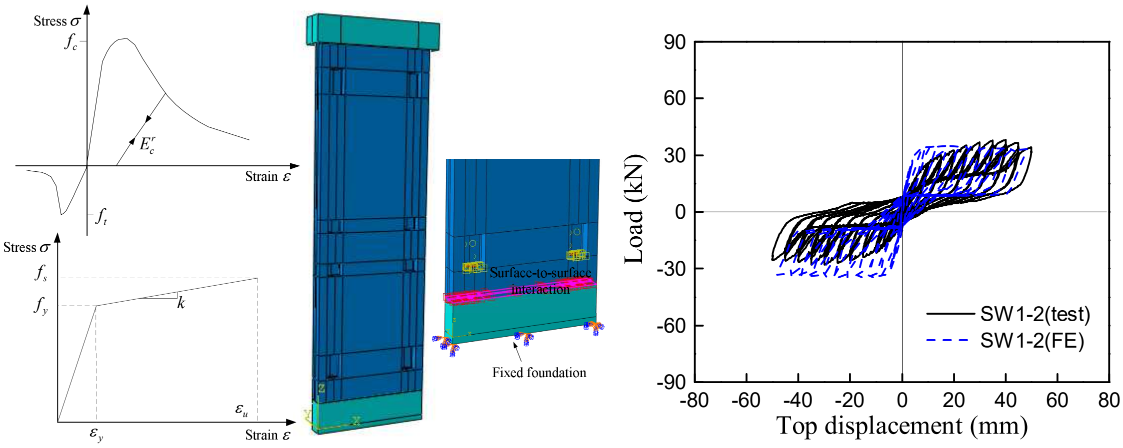


Fig. 2. FEA model and comparison of a typical test specimen

Applying proposed FEA models, a parametric study was conducted to assess the effects of main structural variables on the seismic behavior of the wall panels.

Calculation method

Combined with the preliminary experimental phenomenon and numerical analysis, it is considered that the pressure is transmitted through the concrete contact in the compression zone, and the tension is transmitted by the tension bolt in the horizontal joint section. The idealized internal force transfer mechanism is proposed in Fig.3 that can be used to determine the bearing capacity. It can be seen that the possible failure modes in the bolted PC wall structures may include: (i) failure of the steel bolts, and (ii) pull-shear damage of the reinforced concrete around the joint. So the tensile capacity of the steel bolt was defined as the minimum of the bearing capacities corresponding to the failure modes. Based on this, a simplified calculation method was proposed to predict the bearing capacity and initial stiffness of the PC wall panels with bolted connections. Fig.4 summarizes the results of bearing capacity predicted by FEA and calculated by the proposed calculation model. The calculation model proposed in this study evaluates the bearing capacity and initial stiffness of all specimens with good accuracy.

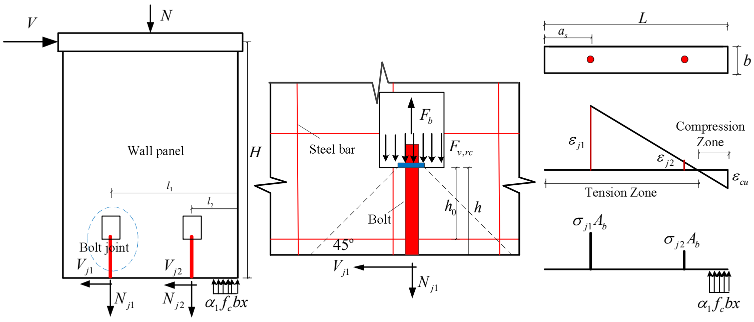


Fig. 3. Schematic outline of forces acting on the horizontal joints

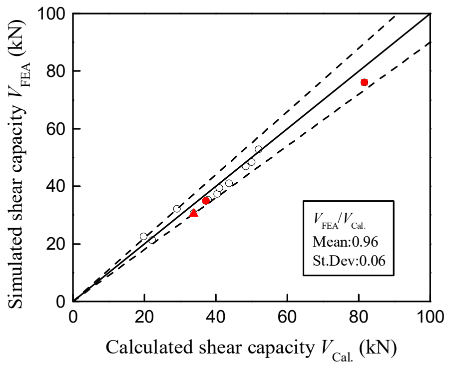


Fig. 4. Comparison between the FEA and calculated results

Achievement

All parts reported here were deeply discussed and summarized in a scientific article that has been submitted to the ***Journal of Building Engineering*** (ELSEVIER, Q1, IF 5.318, ranking it 13/136 in civil engineering).

Acknowledgment

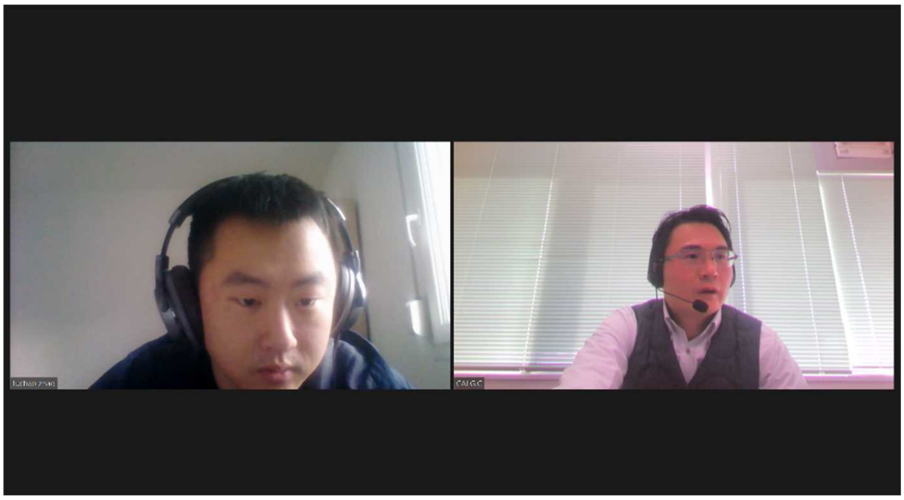
I have been a part of the IROAST internship program from January 17 until February 25. My research interests and passion are in the field of demountable PC structure. Under the supervision of Prof. CAI, I completed the analysis of the test results and the improvement of the FE model. Due to the COVID-19, the internship program has to change to online. However, I still deeply feel the warm help from Prof.CAI as well as the Kumamoto University for the experience.

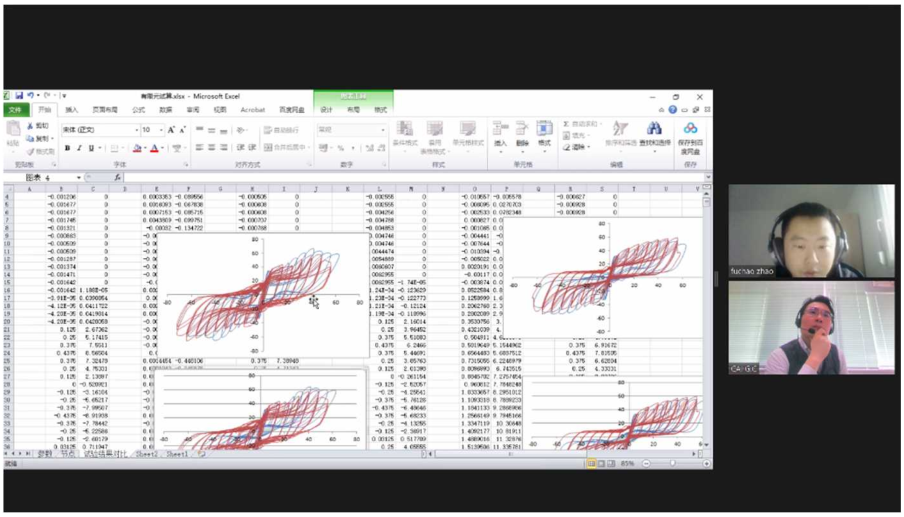
Future research plans

- Summarize the different bolt connection forms. Clarifying the differences in failure modes, hysteresis behavior, stiffness, and strain distribution of PC structure with different bolt connection types
- Investigating the influence of vertical joints on the deformation and strength of the overall structure.
- Investigating the ductility performance of wall panels with bolted connection, and carrying out the performance-based seismic design index of the structure.

Appendix

The following photos show what the internship looked like at that time.




fuchao zhao

No.7-6	The bond performance mechanism of the composite layer–original concrete interface under the main aggressive environment		
Name	Wei Liu		
Affiliation	Université de Lyon, ENISE Email: liuwei_fem@163.com	Title/ Status	PhD Student
Research Field	Composite materials and structures, finite element analysis		
Period of Internship	January 20, 2022-February 18, 2022		
Host Professor	Dr. Gaochuang Cai		
Affiliation	IROAST Email: cai@kumamoto-u.ac.jp	Title	Associate Professor

1. Details of activities

The IROAST research internship program provided me a great chance to have more experience in researching **the bond performance mechanism of the composite layer–original concrete interface under the main aggressive environment**.

1.1 Background

Textile-reinforced concrete(TRC) has emerged in recent years as a new and valuable cement-based composite reinforcement construction material with superior tensile strength and ductility(Fiore et al., 2015). Due to its excellent mechanical properties, good crack limit performance and superior properties on corrosion resistance, the structural designers and architects have developed many exotic light-weight and stiff structures including new structural panels, impact, blast resistance, repair and retrofit, earthquake remediation, strengthening of unreinforced masonry walls, and beam-column connections(Wang et al., 2018). Meanwhile, the mechanical properties and durability under main aggressive environment and various impacts such as chloride salt erosion environment and periodic wet-dry cycles, hot-cold cycle, freeze-thaw cycle, and high temperature is primarily governed by interfacial bond characteristics between fabrics and matrix. Such aggressive environments represent very severe conditions to which the material is subjected. Therefore, the bond performance mechanism of the interface is a key issue when considering composite structural material. However, there is a lack of information about TRC/TRM in these fields.

During the IROAST research internship, two parts of the tasks have been completed. One is the literature investigation of the TRC-concrete bond behavior under various impacts and another is the finite element analysis(FEA) of tensile properties of TRC thin layers using the Concrete Damaged Plasticity (CDP) model. The tasks I engaged in and the results of the research project are described in the following sections.

1.2 Literature investigation

When a TRC/TRM layer is exposed to an external environment, it may be the subject of various attacks, and its durability can be reduced. Therefore, the bond performance mechanism of the TRC composite layer-original concrete interface becomes one of the most essential scientific problems. In fact, the effectiveness of the strengthening systems is influenced significantly by the bond properties of the adhesive between the advanced composite and substrate interface(Al-Jaberi et al., 2019). Within this frame, the understanding of the TRC-original concrete interface deterioration mechanism under chloride ion, wet-dry and freeze-thaw cycles environmental conditions is an instrumental topic and has concentrated many previous works. Furthermore, reliable methods need to be developed both theoretically, experimentally and numerically.

In the last few years, an increasing interest has been given to the use of TRC/TRM as alternatives for conventional reinforcements in composites. The development of commercially viable composite materials based on resource-saving is on the rise. In this sense, TRC/TRM as reinforcements for cement mortar composites constitutes a very interesting topic for researchers. Figure 1 shows the number of publications of TRC/TRM in recent years. As we can see in the picture, in the nearest few years, the number of publications every year is four to five times what it was a decade before. Furthermore, in the process of literature investigation, it can be found that most of the research focused on experimental methods, at the same time, numerical simulation and theoretical research are relatively small. The main experimental methods are pull-out tests(Shiping Yin et al., 2019), uniaxial tensile tests(Colombo et al., 2015), Tensile test(Michels et al., 2014), double-side shear test(Shi-ping Yin et al., 2018), direct shear (Al-Jaberi et al., 2019),four-point bending test(Bisby et al., 2011) and six-point bending test(Michels et al., 2014) et al.

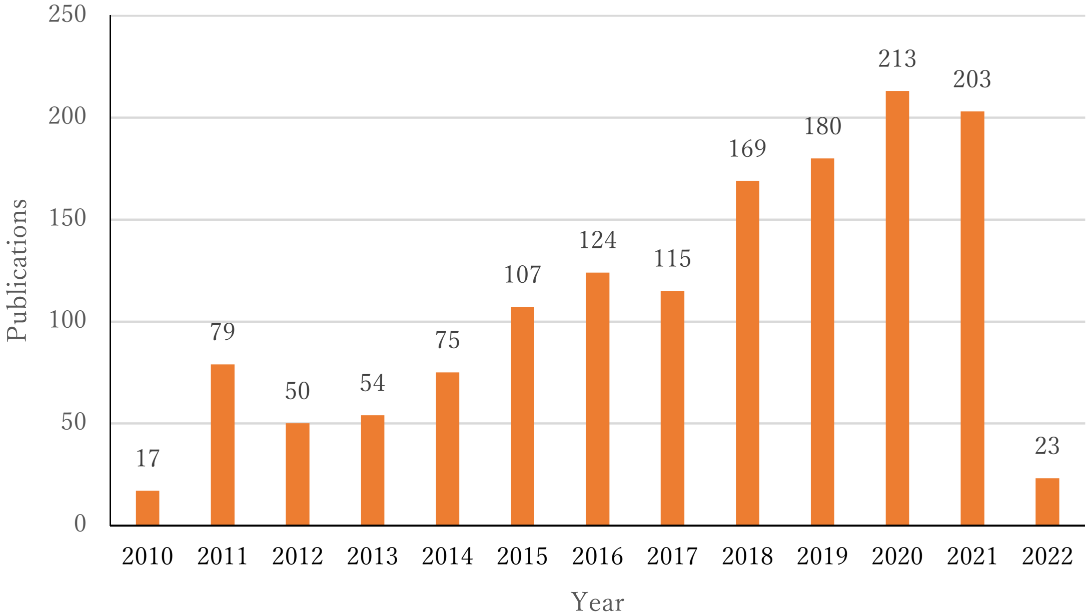


Figure 1 The number of publications of TRC/TRM in recent years

Table 1lists the overview of previous studies regarding TRC/TRM and its sub-topics obtained from a literature investigation in Web of Science. As shown in this table, interfacial bond behavior and flexural behavior of TRC/TRM attract the main attention of researchers. The top three authors with the most published papers in related fields and the number of their publications are also listed here. It can be found that most of the studies have been performed in Germany, China, and Italy.

Table 1 Overview of previous research on TRC/TRM and related topics

Topic	Sub-topic	Total number of publications*	Authors (top three of publications)	Country	Number
Textile reinforced mortar Or Textile reinforced concrete	-	1,614	Hegger Josef	Germany	75
			Curbach Manfred	Germany	59
			Yin Shiping	China	56
	Bond behavior	549	De Felice Gianmarco	Italy	24
			De Santis Stefano	Italy	13
			Bournas Dionysios A.	England	19
	Shear strengthening	234	De Felice Gianmarco	Italy	16
			De Santis Stefano	Italy	16
			Larbi, Amir Si	France	12

	Flexural behavior	405	Yin Shiping	China	23
			Xu Shilang	China	10
			Gopinath Smitha	India	7
	Seismic behavior	139	Triantafillou Thanasis C.	Greece	18
			Bournas Dionysios A.	Greece	11
			Yin Shiping	China	8
	Pullout properties	75	Mechtcherine Viktor	Germany	13
			Hempel Simone	Germany	7
			Butler Marko	Germany	5
	Corrosion environment	31	Yin Shiping	China	14
			Li Yao	China	4
			Yu Yulin	China	4
	Wet-dry cycle	18	Yin Shiping	China	9
			Jing Lei	China	3
			Al-Lami Karrar	Italy	2
	Hot-cold cycle	2	Azimpour-Shishevan Farzin	Iran	1
			Mumenya		1
	Freeze-thaw cycle	22	Yin Shiping	China	4
			Colombo Isabella Giorgia	Italy	2
			Colombo Matteo	Italy	2
	High temperature	164	Cherif Chokri	Germany	6
			Choi Kyoung-Kyu	South Korea	5
			Bournas Dionysios A.	England	4

* The statistical period is from 1950 to 2022 and the database is updated to 22/02/2022.

Figure 2 is the percentage of publications on TRC/TRM research subtopics. Although some of these statistics are repetitive, it largely reflects research trends in the TRC field. As mentioned above, research on TRC is mainly focused on the experimental test. As a new type of composite material, its application scenarios will inevitably become more and more extensive with the deepening of research.

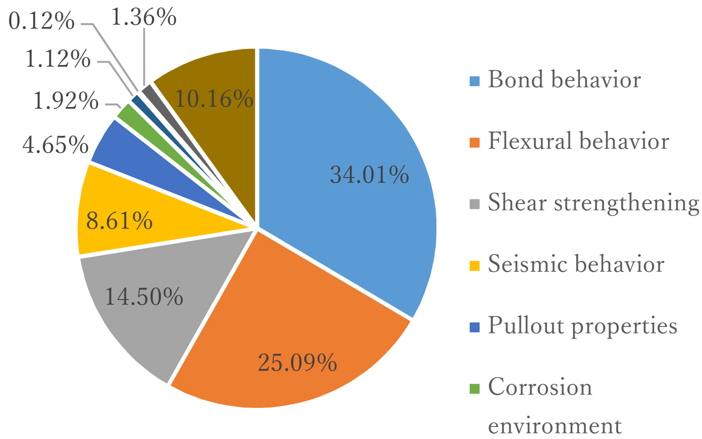


Figure 2 Percentage of publications on TRC/TRM research subtopics

1.3 Finite element modeling and results

Nonlinear finite element analysis of tensile properties of TRC thin layers under static loading was conducted to investigate their failures modes in terms of pullout load and cracking patterns. Among the constitutive models for simulating the behavior of concrete, the concrete damaged plasticity(CDP) model that ABAQUS offers was chosen.

In geometrical modeling of the TRC thin layer, the length of the model is 500mm, the width is 60mm, and the thickness is 10mm. A pressure of 5MPa was applied to steel plates and its dimension was length 160mm×width 60mm×thickness 1mm. The loading scheme was displacement controlled by a loading rate equal to 0.05mm/s. To model specimens having internal AFRP, an 8-node linear tetrahedral element(C3D8) was used for the concrete, AFRP, and steel plates. In the C3D8 element, each node has three translational degrees of freedom in the x, y, and z directions.

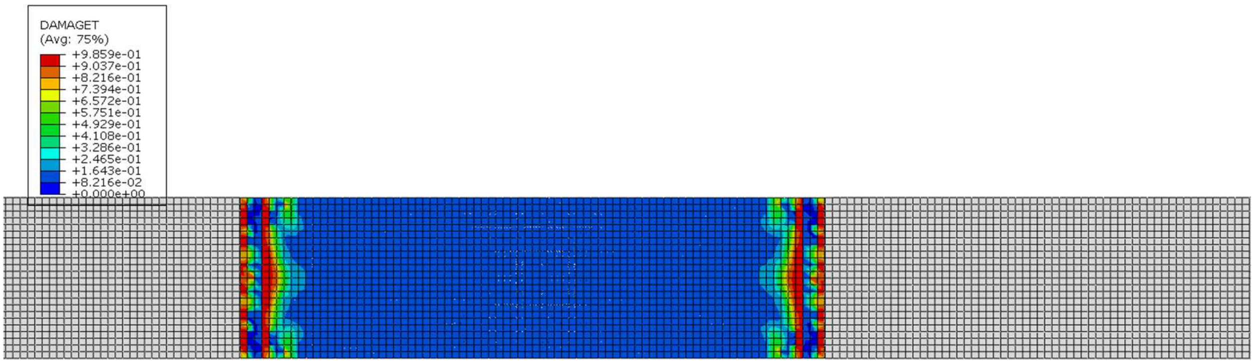


Figure 3 Cracking pattern of TRM specimen

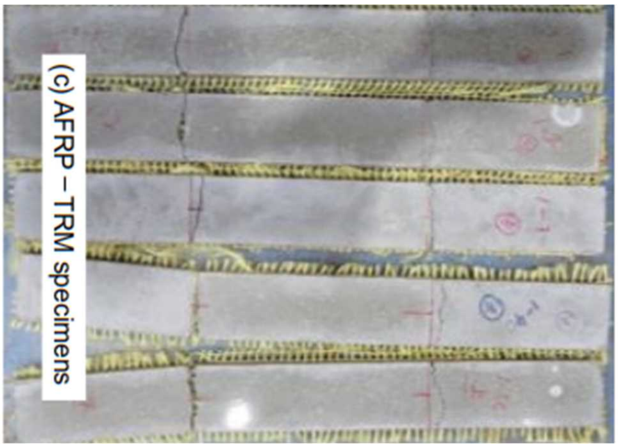


Figure 4 Ultimate cracks and damages of TRM thin layer

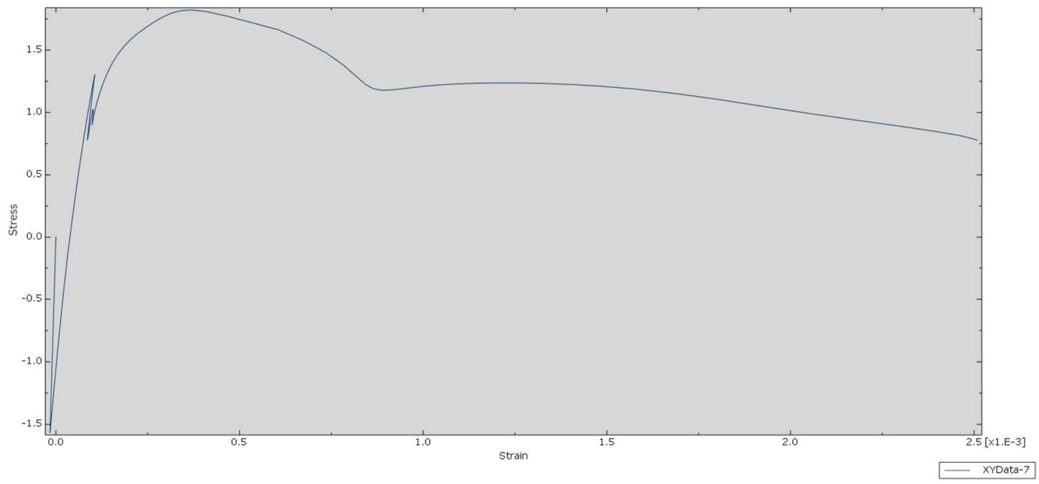


Figure 5 Tensile responses of TRM thin layer

Figure 3 represents the failure mode of the simulated TRC layer. A failure occurred at the end fixture of the specimens. The main reason was considered that the textile mesh was too weak for the TRM thin layer. Figure 4 shows the experiment result. Through comparing the two figures, it can be found that the results of the cracking pattern matches well.

Figure 5 shows the tensile responses of the TRM thin layer. It shows that up to the tensile strength of the AFRP, the stress of TRM grew rapidly before the first crack appeared and the stress of concrete reaches 0.78MPa. After that, the stress-strain curve continues to grow until a second crack appears. and the ultimate stress of concrete reached to 1.81MPa. However, after the peak load, the stress of concrete decreases with the increase of strain, which indicated that the AFRP's contribution to resisting tensile load has increased. From the numerical simulation results, it can be found that the size of the loading displacement, the pressure of the steel plates, and the loading time (loading step) have a great influence on the results.

2. Future research plans

At present, a number of studies on literature investigation have been done during the IROAST internship. However, there are still some aspects that need to be further studied in the future, the most crucial among them is the numerical simulation method on the bond performance mechanism of the TRC interface under the main aggressive environment and it is necessary to engage in this research field. On the other hand, the current numerical simulation analysis needs to be completed as soon as possible.

3. Achievement

Based on the above research work, two papers will be published. One is a literature review paper about the bond performance mechanism of the composite layer–original concrete interface under the main aggressive environment. And another is about the tensile properties of an improved TRC.

4. Acknowledgement

I am extremely grateful to Kumamoto University for fully supporting this project. The organizing committee of the IROAST research internship program made great efforts to make the program go on wheels. Participating in the IROAST Research Internship Program at Kumamoto University was a great honor and an unforgettable experience. Finally, I especially appreciate Dr. CAI for helping me complete this research. Without his guidance, none of this would have been possible.

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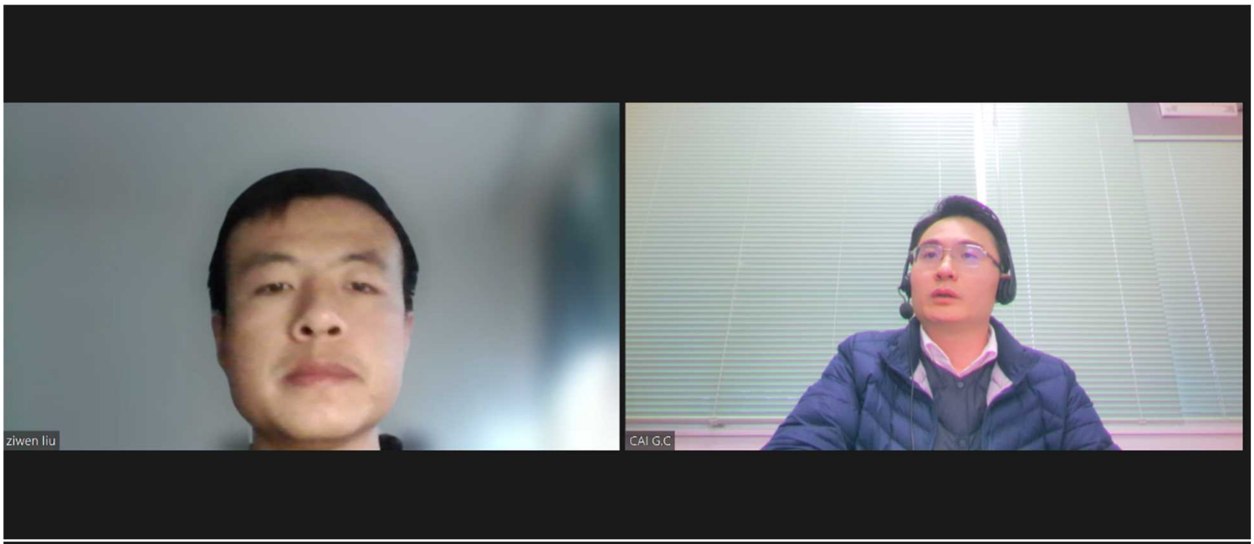
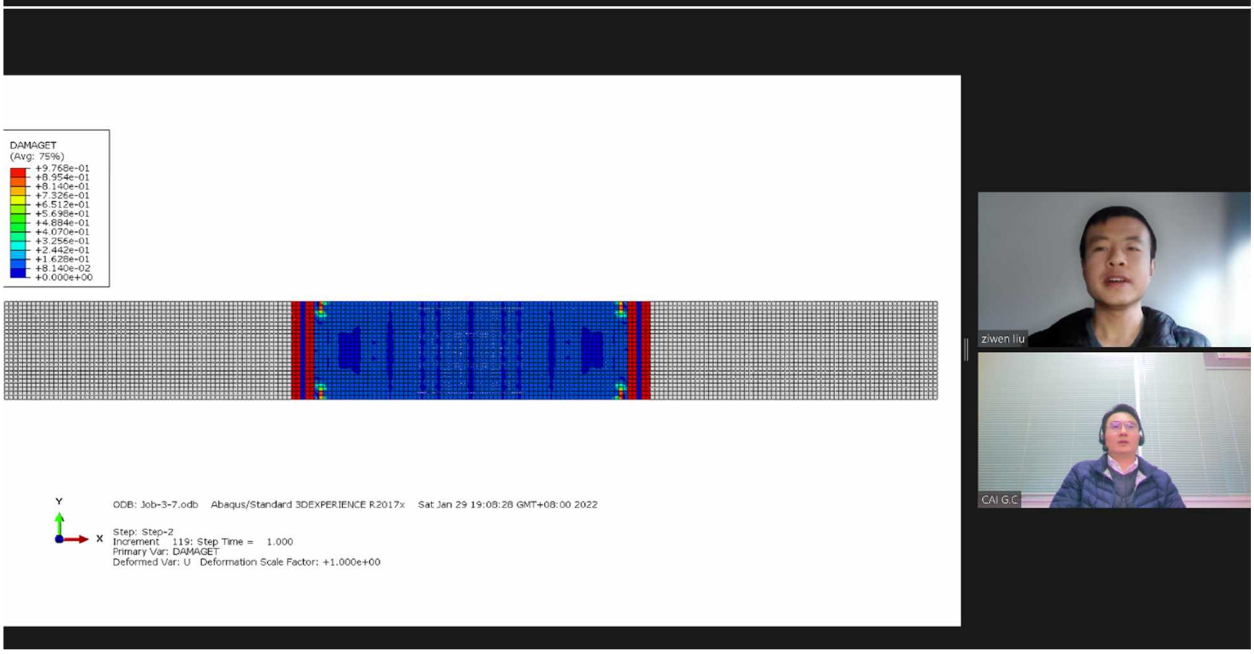
Appendix

The following photos show what the internship looked like at that time.





No.7-7	Bond performance between carbon fiber reinforced polymer bars and ultra-high-performance concrete		
Name	Yunjian He		
Affiliation	Zhengzhou University Email: heyunjian1996@163.com	Title/ Status	Graduate Student
Research Field	Concrete Structures		
Period of Internship	January 20-February 25, 2022		
Host Professor	Gaochuang Cai		
Affiliation	IROAST Email: cai@kumamoto-u.ac.jp	Title	Associate Professor

Due to various reasons, this year's internship was an online internship. Although I was not able to go to Kumamoto University, the online internship increased the opportunity for me to communicate and exchange ideas with my host professor, Gaochuang CAI. Whenever I asked Professor Cai for advice, he always replied quickly and explained patiently. I sincerely thank Professor CAI for his help. The topic of my internship program is "Bond performance between carbon fiber reinforced polymer bars and ultra-high-performance concrete", and I will describe what I have gained from this internship in the following aspects.

Research background

Carbon fiber reinforced polymer (CFRP) bars are characterized by high tensile strength, corrosion resistance and lightweight, and can be used to replace steel bars to fundamentally solve the corrosion problem of steel bars. However, CFRP bars are brittle materials and in combination with conventional concrete, the ductility of the structure is often poor. To improve the ductility of CFRP reinforced concrete structures, ultra-high performance concrete (UHPC) with high compressive strength and large ultimate compressive strain can be used instead of conventional concrete. The combined structure made of CFRP bars and UHPC will have excellent durability. In addition, UHPC structures tend to be smaller in size, which greatly reduces the dead weight of the structure, reduces the amount of cement used, and is in line with the low carbon concept. The precondition for CFRP bars and UHPC to work together is a reliable bond and anchorage between them. For this purpose, this program investigated the bond performance between CFRP bars and UHPC using the hinged beam test, which can take into account the combined effect of bending moment and shear force, better simulate the bonding of FRP bars at the end of the beam, and is more in line with the actual state of force than the pull-out test.

Tasks and results

1. Analysis of the test result

In Fig. 1 each curve showed an almost infinite slope at the initial stage, and the bond strength was mainly provided by the chemical adhesive force and static friction at this time. As the load continues to increase, the chemical adhesive force was lost, the bond stress turned to be provided by friction and mechanical interlocking together, and the CFRP tendon surface ribs were gradually peeled off. When the bond stress reached its peak, the ribs in the bond section had all been destroyed, and the bond stress dropped to its lowest point when the slip reached slightly less than one rib spacing. Subsequently, the bond stress gradually rose, which was due to the rib on the free end entering the bonded section, increasing the mechanical interlocking and friction at the bonded interface. After the slip passed through approximately another one rib spacing, the bond stress dropped to its lowest point again and the tendons on the free end side gradually slipped into the bond section, causing the curve to fluctuate periodically. At the end of the test, the beam was split as shown in Fig.2 which revealed that the entire outer surface at the bonded section was attached to the concrete surface and the ribs had been completely peeled off from the inner core material. It was worth noting that the number of peak points in the bond-slip curve was equal to the number of ribs entering the bond section from the free end.

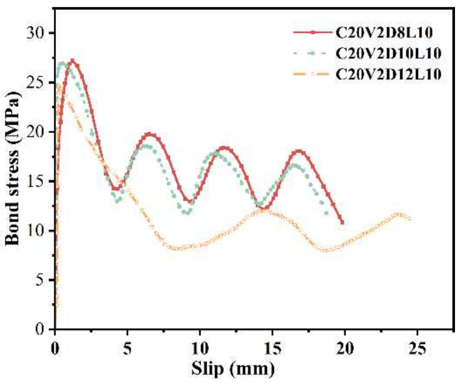


Fig.1 Bond-slip curves under different diameter

Fig.2 Bond failure

Fig. 3 showed the bond strength and slip of the test. When the diameter was increased from 8mm to 10mm, the ultimate and residual bond strengths were reduced by 6% and 11% respectively. The 12mm CFRP tendon, on the other hand, had a different surface form, which was notable for a greater slip in the descending section of the curve and a smaller ratio of residual bond strength to ultimate bond strength. The slip (s_u) corresponding to ultimate bond strength increased almost linearly with increasing rib spacing, for S8 and S10 CFRP bars with a rib spacing of 5.25mm and D12 CFRP bars with a rib spacing of 10.2mm, the slip s_u was 4.16mm, 4.27mm, and 9.11mm, respectively. Meanwhile, the residual section can be regarded as a sinusoidal curve with one rib spacing as the period, which provided a reference basis for modeling the bond stress-slip constitutive relation of CFRP tendons in UHPC.

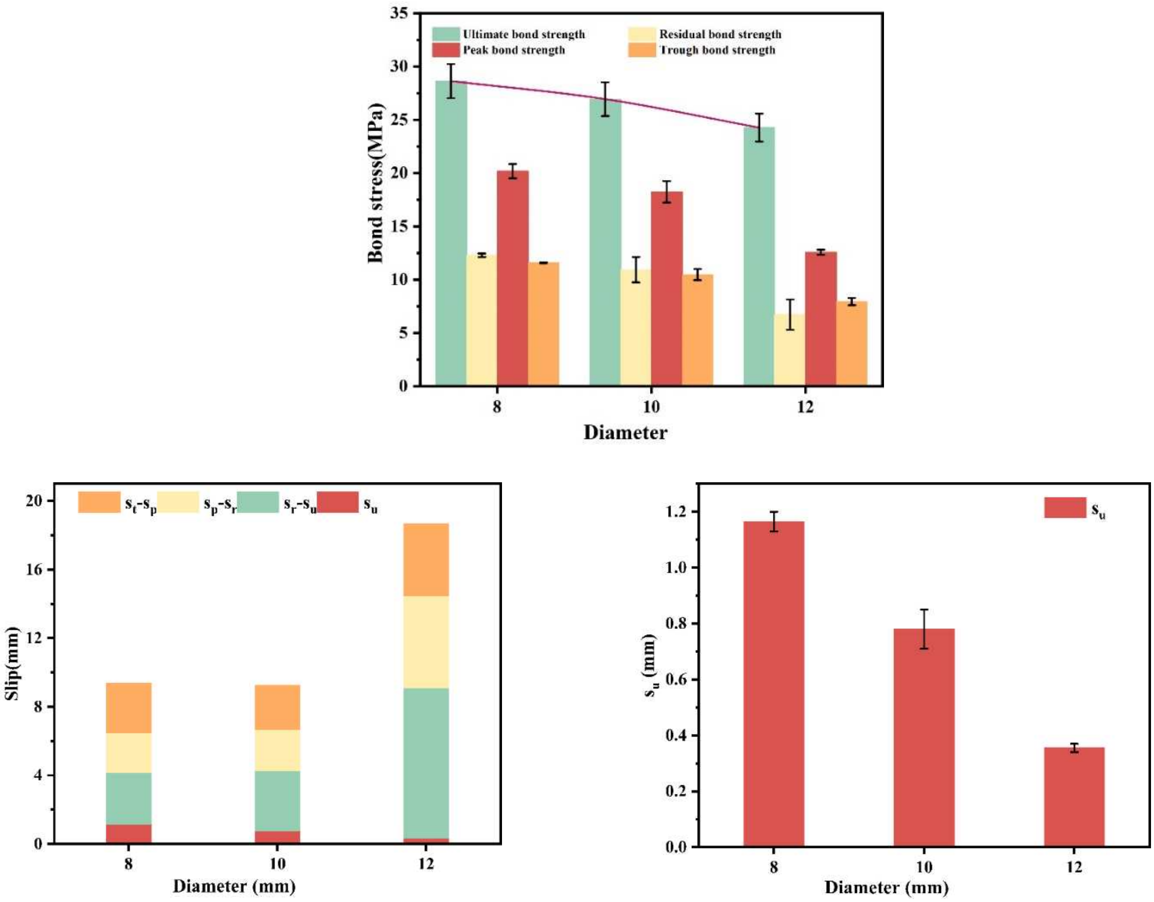


Fig.3 Bond strength and slip under different diameter

2. Calculation of bond strength between CFRP tendons and UHPC

ACI440.1R-15 used a linear regression of Wambeke and Shield's database of 269 beam tests established to derive the formula for calculating the bond strength of FRP bars to concrete. Combined with the data in this paper, it was found that as the bond length decreases from 10db, to 7.5db, 5db, and 2.5db successively, the predicted value of ACI for the bond strength of this test increased almost linearly, which was due to the fact that the ACI calculation formula for db/le had a large fixed factor, and it can be predicted that as the bond length continues to decrease from 2.5db, the calculated ACI value will be greater than the measured value. Referring to the ACI calculation method, the bond strength calculation equation was obtained by fitting the data from this test through linear regression which can reflect the bond strength of CFRP tendons and UHPC more accurately as shown in Fig. 4.

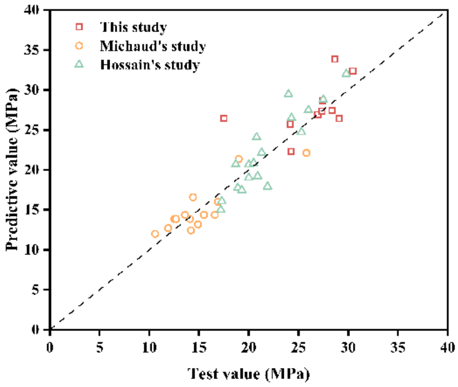


Fig.4 Fitting results of bond strength calculation formula

3. Development length and bond stress-slip constitutive relationship between CFRP tendons and UHPC

Development length was obtained by combined equilibrium formula and bond strength formula. Taking the data from this test and giving a conservative value, the basic development length of CFRP bars in UHPC can be obtained as 40db. This research described the whole process of bond stress-slip constitutive relation in three stages: ascending section, descending section, and residual section. According to previous studies, there were Malvar model, MBPE model and CMR model for the bond-slip constitutive relationship between FRP bars and concrete. Since the Malvar model had a complex form and the initial slope was not infinite, which was not consistent with the actual situation. To obtain a more accurate fitted model, ascending section of the MBPE model was compared with the CMR model. By comparing the fitting results, it was found that the CMR model fitted the rising section better (mean R2 = 0.98, C.V.= 0.78%) than the MBPE model (mean R2 = 0.79, C.V.= 13.8%). A sine function was used to represent the descending section of the bond-slip curve (mean R2 = 0.99, C.V.= 2.29%) and a decaying sine function to represent the periodic fluctuations in the residual section (mean R2 = 0.78, C.V.= 13.9%), achieving a relatively well-fitted result. Fig. 5 listed the experimental and model curves of bond-slip curves with different CFRP tendon diameters.

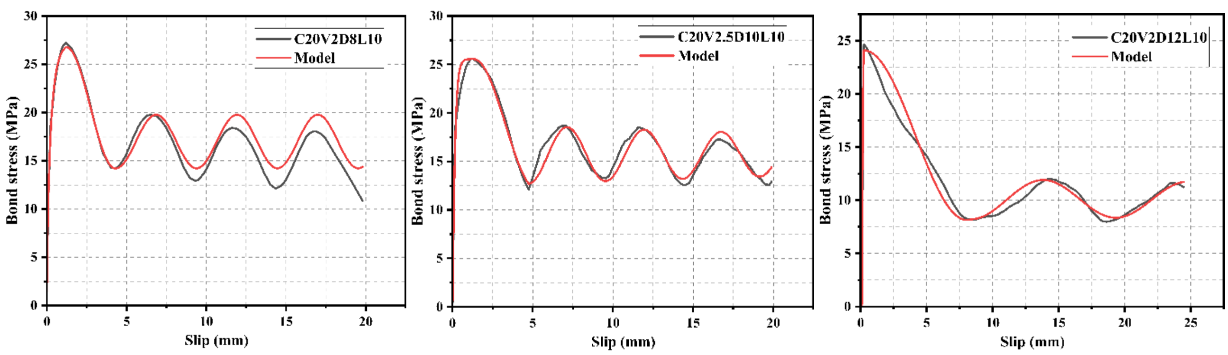


Fig. 5 The experimental and model curves

Achievement

All parts reported here were deeply discussed and summarized in a scientific article that has been submitted to the journal of ***Construction and Building Materials*** (ELSEVIER, Q1, IF 6.141, ranking it 7/136 in civil engineering).

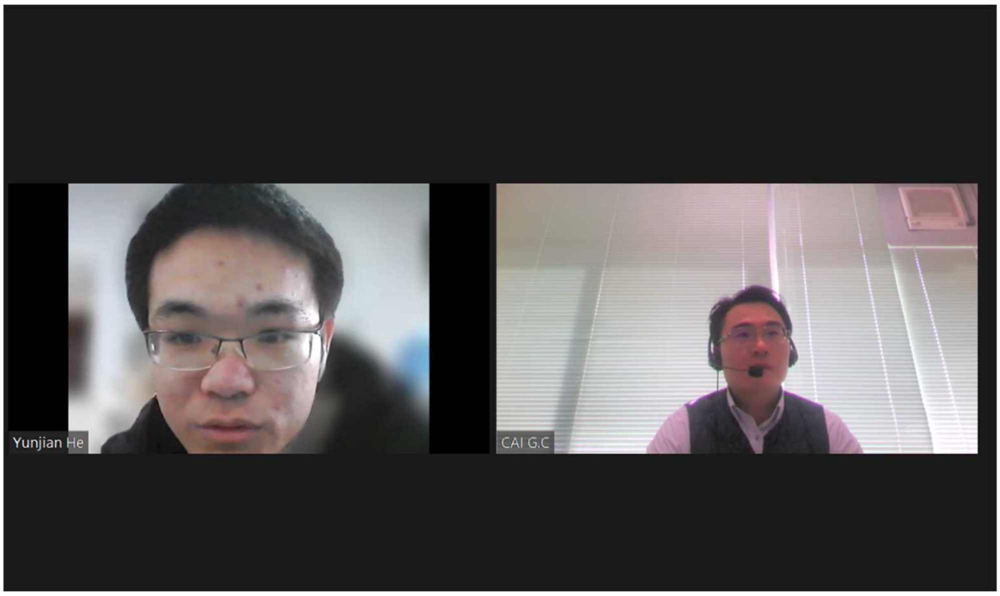
Future research plans

Japan is an earthquake-prone country and is a world leader in structural seismic technology. Currently, most of the experimental studies on the seismic performance of FRP strengthened RC structures are focused on ordinary ground motions, and there is a lack of quantitative assessment of the performance and damage of FRP strengthened RC structures subjected to long-period ground motions. However long-period ground motion is rich in low-frequency components, it is easy to produce a "resonance-like" effect with the building structure with a long self-oscillation period, thus causing some special earthquake damage. Therefore, the seismic strengthening of existing long-period structures requires consideration of the effects of long-period ground motion. At the same time, the residual seismic performance of the strengthened structures after long-period ground motions has also been little studied, so it is necessary to study the repair methods and the seismic performance of the repaired damaged structures. The research results will have realistic engineering significance and important theoretical value for guiding the strengthened design. In this research, the performance of FRP strengthened RC columns under long-period ground motions will be analyzed and compared with normal ground motions to analyze the similarities and differences between them, and the residual seismic performance of the strengthened columns after experiencing long-period ground motions will be investigated. In addition, the numerical analysis will be used to investigate the key parameters affecting the FRP strengthened RC structures. The main research includes:

- Studying the compressive strength, ductility, and uniaxial compression constitutive model of FRP-confined concrete;
- Investigating the damage modes, damage mechanisms and energy dissipation performance of FRP strengthened RC structures under long-period ground motion and making comparative analysis with common ground motions;
- Considering the effects of different test parameters such as FRP strengthening methods, lateral displacements, and types of ground motions on the seismic performance of the structure, and conducting parametric analysis of the seismic performance of FRP strengthened RC columns using finite element numerical models;
- Suggesting and verifying several repair methods for damaged columns and studying the recovery of seismic performance of repaired columns under seismic re-activation;
- Combining experimental data and finite element calculations to establish the damage model of FRP-reinforced RC structures under long-period ground motion.

Appendix

The following photos show what the internship looked like at that time.



Yunjian He
CAI G.C

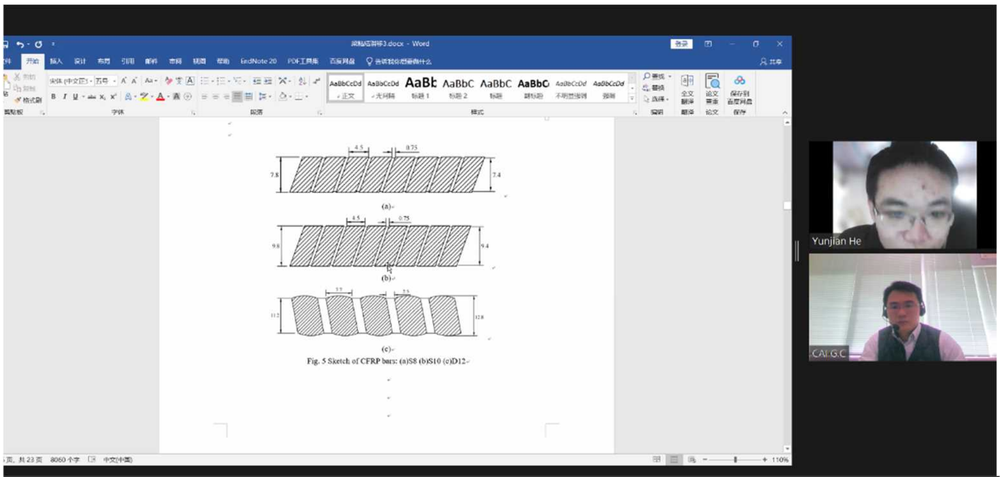
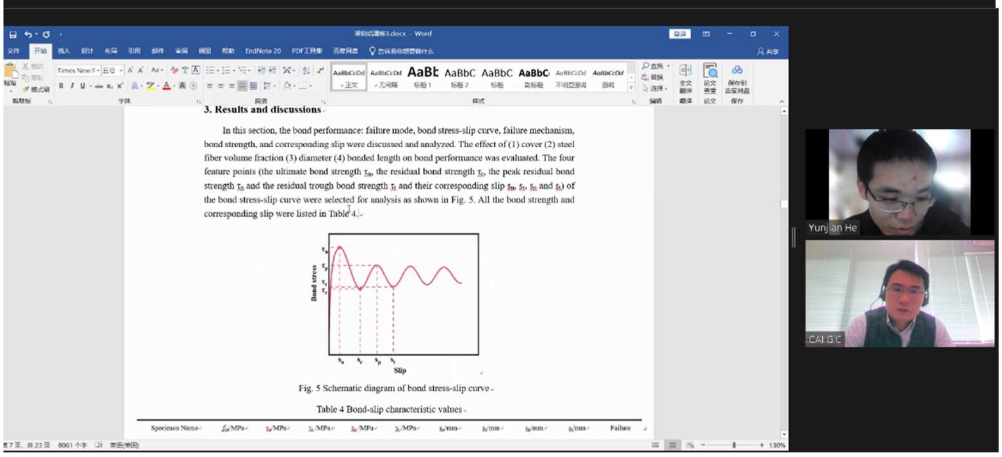


Fig. 5 Sketch of CFRP bars: (a)S8 (b)S10 (c)D12
Yunjian He
CAI G.C



3. Results and discussions
In this section, the bond performance: failure mode, bond stress-slip curve, failure mechanism, bond strength, and corresponding slip were discussed and analyzed. The effect of (1) cover (2) steel fiber volume fraction (3) diameter (4) bonded length on bond performance was evaluated. The four feature points (the ultimate bond strength τu, the residual bond strength τr, the peak residual bond strength τp and the residual trough bond strength τt and their corresponding slip su, sr, sp and st) of the bond stress-slip curve were selected for analysis as shown in Fig. 5. All the bond strength and corresponding slip were listed in Table 4.
Bond stress
Slip
Fig. 5 Schematic diagram of bond stress-slip curve
Table 4 Bond-slip characteristic values
Yunjian He
CAI G.C

No.7-8	Study on Oxygen Diffusion of Eco Concrete subjected to Loads		
Name	Chenggong Cai		
Affiliation	Jiangsu University of Science and Technology Email: 331361674@qq.com	Title/ Status	Graduate Student
Research Field	Green Energy/ Environmental Science		
Period of Internship	January 31-February 21, 2022		
Host Professor	Gaochuang Cai		
Affiliation	IROAST Email: cai@kumamoto-u.ac.jp	Title	Associate Professor

First of all, I am honored to have this opportunity to exchange and study with Professor Cai from Kumamoto University. It is a very pleasant process. Due to the COVID-19, this exchange and study were forced to use online video, but this did not stop our enthusiasm for academic exchanges. Here, I would like to thank Professor Cai again for his concern and help to me, which made me feel the strong academic atmosphere of Kumamoto University. Thank you very much.

Secondly, in terms of academic research, I mainly study the oxygen diffusion under ecological concrete load. In the early stage of the research, I mainly conducted a background investigation on the research on the gas diffusion of ecological concrete, starting with the device and physical experimental method for measuring the gas diffusion coefficient. Secondly, based on background research, the experimental method of gas diffusion research under ecological concrete load is determined. Finally, combined with COMSOL simulation analysis software, an oxygen diffusion model was established, and the oxygen diffusion of ecological concrete under different loads was studied and analyzed by using the model. The ultimate goal of this study is to obtain the oxygen diffusion rate in concrete to predict reinforcement corrosion and ultimately improve the durability of concrete.

In the future, I will actively use the combination of the ecological concrete gas diffusion research test method and numerical analysis software simulation method to carry out further research. An ecological concrete model with different aggregate distributions and an oxygen diffusion prediction system under different loads are established to provide a reference for predicting steel corrosion in the future. At the same time, after this research, the unexpectedly discovered factors such as temperature, saturation, and load coupling effect analysis of ecological concrete gas diffusion will be closer to the actual project, and more intuitively understand the life state of concrete in the actual project service state, which will It is of great significance to the study of concrete durability.

1. Existing Oxygen Diffusion Plant

Through the investigation of the background of concrete gas diffusion, we found that researchers Geng Ou et al. developed a concrete oxygen diffusion coefficient test device. The device is used to determine the relationship between the oxygen diffusion coefficient of concrete materials and concrete water-cement ratio, relative humidity, and ambient temperature. Influence last.

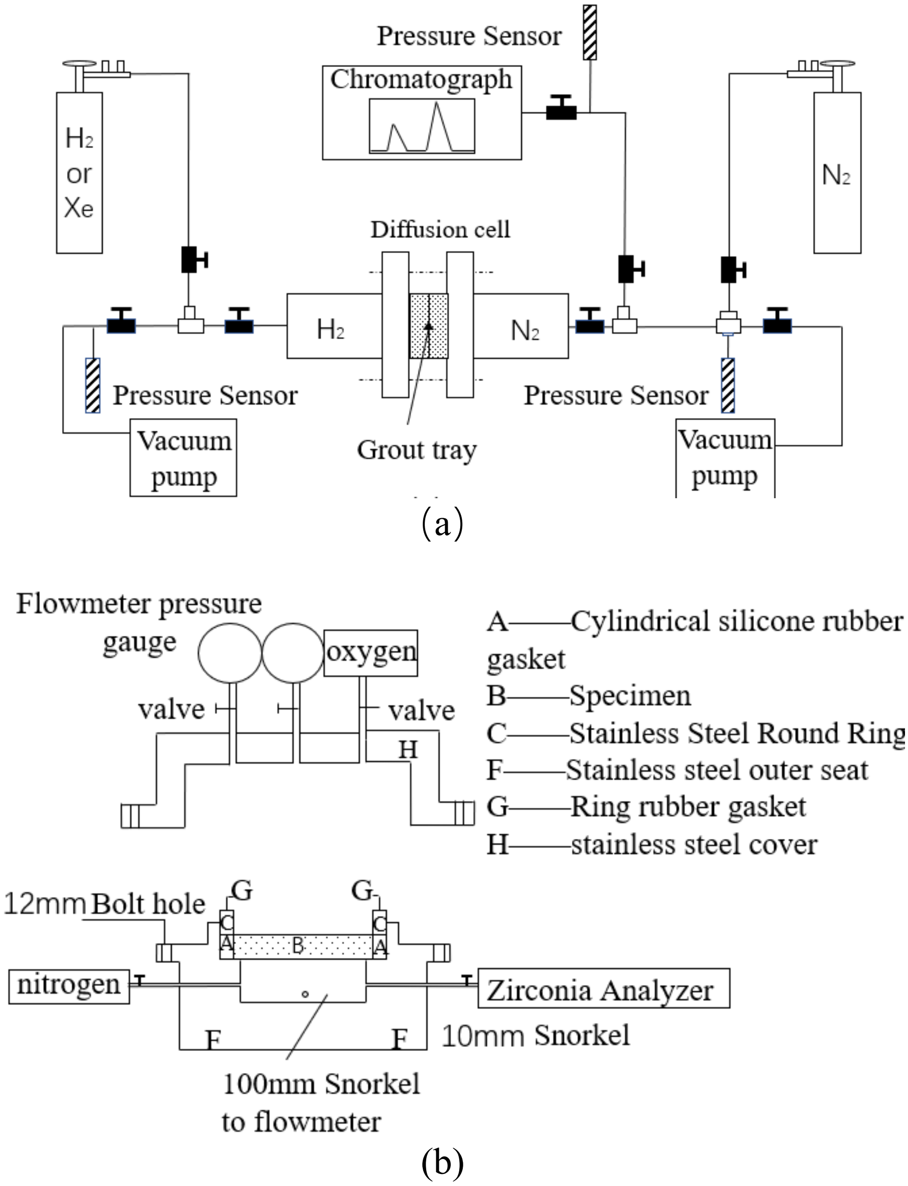
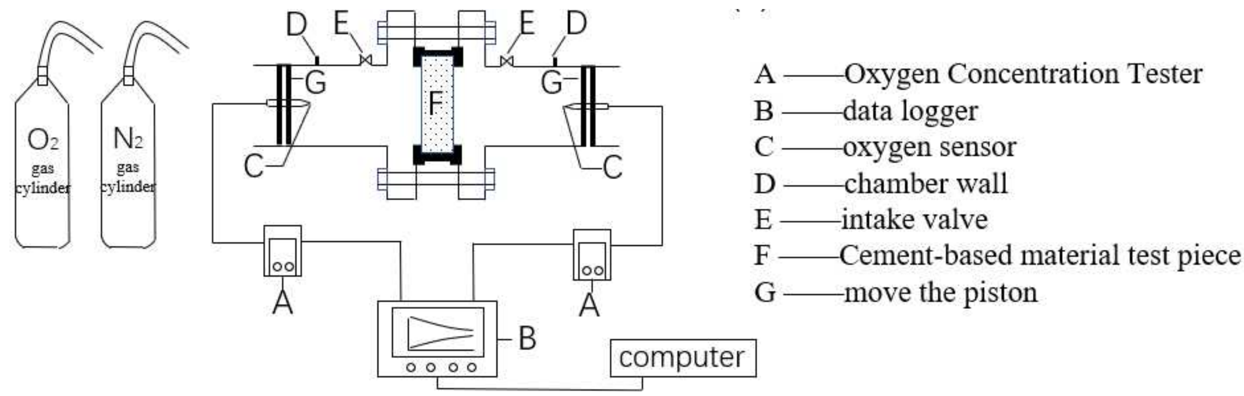


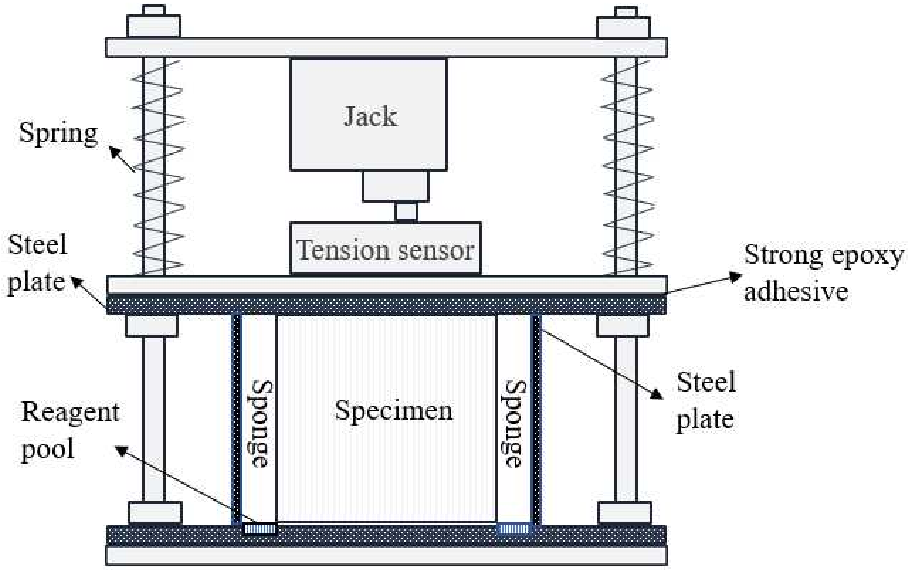
Fig1. Existing Oxygen Diffusion Coefficient Measuring Devices

2. The measuring device for this study

With the research background of the above-mentioned oxygen diffusion coefficient measuring device, combined with the load factor of this subject, we have redesigned the oxygen diffusion coefficient measuring device of concrete. The device includes two parts, the first part is the oxygen concentration measurement part, and the second part is the loading device, the combination of the two is used to measure the oxygen diffusion coefficient of the bio-concrete under the load. Among them, the upper and lower parts of the specimen are subjected to load, and a group of opposite surfaces around them is in contact with the sponge soaked in water so that the subsequent saturation affects the oxygen diffusion, and the other group of opposite surfaces is tested for the oxygen diffusion coefficient. The specific measurement device diagram is shown in Figure 2.



(a) Oxygen Diffusion Coefficient Determination Section



(b) Loader section

Fig2. Device for measuring oxygen diffusion coefficient of ecological concrete under load

3. Numerical Simulation

Here we use COMSOL software to establish an oxygen diffusion model, the aggregates inside the model are randomly distributed, and use the same set of data to simply test the oxygen diffusion of ecological concrete generated by different loads. Among them, considering the influence of load factors on oxygen diffusion, when establishing the oxygen diffusion model, we use cracks to represent the influence of load factors on the specimen. We simplified the cracks generated by the load on the model into one crack and three cracks for comparative analysis. It is not difficult to find that the oxygen diffusion rate of the samples at both cracks is significantly faster than that of the uncracked area, and the diffusion rate of the sample interface transition area is significantly faster. In addition, through careful observation, it can be found that at the same time and the same temperature, the oxygen diffusion rate of the three-crack specimen is faster than that of the one-crack specimen. Moreover, the oxygen diffusion rate in the interface transition area of both is inconsistent with the surrounding area, and the related research on oxygen diffusion in the interface transition area will be reflected in the follow-up research.

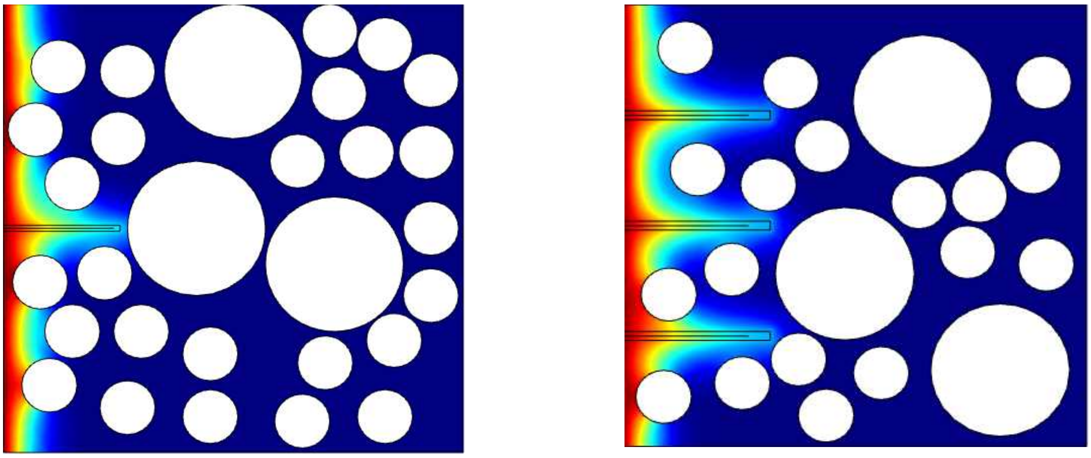


Fig 3. COMSOL numerical simulation results of oxygen diffusion in concrete

The following photo shows what the internship looked like at that time.