Project Completion Report

Project for Evaluation and Mitigation of Seismic Risk for Composite Masonry Buildings in Bhutan

June 2023

Japan International Cooperation Agency
(JICA)

Nagoya City University

IM
JR
23-080

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I. Basic Information of the Project

1. Country

Bhutan

2. Title of the Project:

Project for Evaluation and Mitigation of Seismic Risk for Composite Masonry Buildings in Bhutan

3. Duration of the Project:

2017/4/27-2022/4/26 (Planned)
2017/4/27-2023/4/26 (Actual)

4. Background (from Record of Discussions(R/D))

Except in urban area including the capital, most of buildings in Bhutan are constructed of indigenous materials and techniques such as rammed earth and random stone masonry and wood. As per the recent statistics, 66% of households in the country, especially 83% of households in the rural areas, live in traditional houses. This community-based practice using indigenous materials and techniques to build home has been as of now vitally sustained in the every corner of the country.

However, remarkable number of buildings constructed of indigenous materials and techniques were destroyed due to earthquakes in 2009 and 2011. It became the critical task for RGoB to guide the citizens to improve the seismic resilience of traditional houses.

In order to tackle the problems, DDM (MoHCA), DoC (MoHCA), Department of Geology and Mines (DGM, MoEA), Department of Engineering Services (DES, MoWHS) and Nagoya City University, NED, Kyoto University, Nihon University, Kagawa University, Tohoku University formulated a proposal of a collaborative research project that aims at the establishment of evaluation and mitigation of seismic risk for traditional houses in Bhutan.

Accordingly, based on the proposal, the Government of Bhutan has requested Science and Technology Research Partnership for Sustainable Development (hereinafter referred to as “SATREPS”) a scientific and technological cooperation program under the framework of technical cooperation of the Government of Japan titled “Evaluation and Mitigation of Seismic Risk for Composite Masonry Buildings in Bhutan”.

5. Overall Goal and Project Purpose (from Record of Discussions(R/D))

Seismic technology for disaster mitigation of the composite masonry buildings is disseminated across the country. The capacity of responsible governmental organizations (DDM, DoC, DGM and DES) for seismic disaster mitigation of the composite masonry buildings in Bhutan is enhanced.

6. Implementing Agency

Department of Disaster Management (DDM), Ministry of Home and Cultural Affairs (MoHCA), Department of Culture (DoC), MoHCA, Department of Geology and Mines (DGM), Ministry of Economic Affairs (MoEA), Department of Engineering Services (DES), Ministry of Works and Human Settlement (MoWHS), Japan International Cooperation Agency (JICA), and Nagoya City University, NED, Kyoto University, Nihon University, Kagawa University, and Tohoku University.

II. Results of the Project

1. Results of the Project

The details are shown in Annex 1.

1-1 Input by the Japanese side (Planned and Actual)

(1) Amount of input by the Japanese side

As planned, the Japanese side provided JPY 54 million as overseas activity costs for the project excluding Japanese experts' overhead costs. As some amount of travel expenditure remained unused due to the movement restriction from March 2020 to July 2022 in the COVID-19 pandemic, approximately JPY 2 million was reappropriated to spend for the website contents creation and equipment procurement for facilitating the Project research by counterparts.

(2) Expert dispatch

The Japanese team dispatched one Chief Advisor, thirteen Experts, four Project Coordinators, and two long-term experts, including JICA Project Coordinator. Since April 2017, a total of 18 short-term experts have been dispatched on 108 occasions for 1068 days, as shown in Table 1-1.

Table 1-1. List of Dispatched Experts

Expert	Name, Title, Organization	Duration
1 Chief Advisor/ Masonry Structures	Mr. Takayoshi Aoki, Professor of Nagoya City University (NCU)	13th May to 21st May 2017 14th Sep to 23rd Sep 2017 22nd Dec to 28th Dec 2017 03rd Mar to 10th Mar 2018 07th May to 15th May 2018 04th Aug to 10th Aug 2018 28th Sep to 05th Oct 2018 16th Dec to 30th Dec 2018 26th Feb to 11th Mar 2019 20th Mar to 24th Mar 2019 10th May to 13th May 2019 09th Oct to 23rd Oct 2019 27th Oct to 31st Oct 2019 08th Dec to 23rd Dec 2019 06th Aug to 22nd Aug 2022 17th Sep to 1st Oct 2022 18th Nov to 28th Nov 2022 16th Dec to 31st Dec 2022 27th Feb to 9th Mar 2023 13th Mar to 20th Mar 2023
2 Earthquake Engineering	Mr. Hiroshi Inoue, Principal Research Fellow of the National Research Institute for Earth Science and Disaster Resilience (NIED)	13th May to 20th May 2017 02nd Oct to 15th oct 2017 10th Dec to 16th Dec 2017 04th Mar to 11th mar 2018 17th Mar to 25th Mar 2018 05th May to 13th May 2018 29th Sep to 07th Oct 2018 03rd Mar to 08th Mar 2019 15th Mar to 23rd Mar 2019 10th May to 12th May 2019 28th Sep to 04th Oct 2019 11th Dec to 23rd Dec 2019 25th Jan to 29th Jan 2020 11th Dec to 31st Dec 2022

		02nd Mar to 22nd Mar 2023
3 Seismology	Mr. Shiro Ohmi, Associate Professor of Kyoto University (KU)	14th May to 21st May 2017 02nd Oct to 18th Oct 2017 03rd Mar to 11th Mar 2018 17th Mar to 30 Mar 2018 08th May to 20th May 2018 10th Sep to 20th Sep 2018 18th Nov to 02nd Dec 2018 24th Feb to 07th Mar 2019 07th May to 20th May 2019 26th Aug to 08th Sep 2019 13th Dec to 22nd Dec 2019 08th Aug to 28th Aug 2022 (18th Mar to 25th Mar 2023)
4 Seismic Engineering	Mr. Noriyuki Takahashi, Associate Professor of Tohoku University (THU)	13th May to20th May 2017 19th Sep to 24th Sep 2017 19th Dec to 24th Dec 2017 16th Dec to 21st Dec 2018 09th May to 13th May 2019 14th Oct to 18th Oct 2019 08th Dec to 12th Dec 2019 17th Sep to 23rd Sep 2022
5 Seismic Engineering	Mr. Mitsuhiro Miyamoto, Associate Professor of Kagawa University (KGU)	13th May to 21st May 2017 17th Sep to 24th Sep 2017 19th Dec to 25th Dec 2017 01st Mar to 10th Mar 2018 04th Aug to 10th Aug 2018 28th Sep to 05th Oct 2018 16th Dec to 30th Dec 2018 26th Feb to 11th Mar 2019 20th Mar to 24th Mar 2019 16th Dec to 30th Dec 2018 02nd Mar to 11th Mar 2019 10th May to 13th May 2019 14th Jul to 18th Jul 2019 09th Oct to 18th Oct 2019

		06th Aug to 22nd Aug 2022 19th Sep to 27th Sep 2022 18th Dec to 31st Dec 2022 11th Mar to 20th Mar 2023
6 Building Materials	Mr. Noboru Yuasa, Professor of Nihon University (NU)	14th May to 22nd May 2017 22nd Dec to 27th Dec 2017 20th Dec to 30th Dec 2018 03rd Mar to 11th Mar 2019 14th Nov to 27th Nov 2022
7 Building Materials	Mr. Tomoyuki Koyama, Associate Professor of Kyushu University	14th Nov to 21st Nov 2022
8 Building Materials	Mr. Takumi Aramaki, Assistant Professor of Institute of Technicians	14th May to 22nd May 2017 13th Sep to 30th Sep 2017 15th Dec to 28th Dec 2017 19th Nov to 1st Dec 2022
9 Building Materials	Mr. Sangchul Shin, Post-doctoral researcher of NU	10th Dec to 30th Dec 2018
10 Masonry Structures	Ms. Junko Mukai, Research Assistant Professor of NCU	01st Aug to 31st Aug 2022 19th Sep to 17th Oct 2022 22 Nov 2022 to 15 Jan 2023 28th Feb to 23rd Mar 2023
11 Masonry Structures	Mr. Shrestha Kshitij Charana, Associate Professor of Tribhuvan University	14th May to 21st May 2017 13th Sep to 30th Sep 2017 14th Dec to 27th Dec 2017 21st Feb to 14th Mar 2018 07th May to 15th May 2018 02nd Aug to 10th Aug 2018 26th Sep to 26th Oct 2018 14 Nov 2018 to 24 Jan 2019 18th Feb to 25th Mar 2019 10th May to 24th May 2019 10th Jul t 30th Jul 2019 09th Oct to 31st Oct 2019 06th Dec to 23rd Dec 2019 05th Jan to 07th Jan 2020

12 Structural Engineering	Mr. Jingyao Zhang, Associate Professor of KU	14th May to 20th May 2017 17th Sep to 23 Sep 2017 16th Dec to 21st Dec 2019 19th Dec to 23rd Dec 2019 18th Nov to 28th Nov 2022
13 Graphic Design	Ms. Junko Mori, Professor of NCU	14th May to 21st May 2017 14th Sep to 19th Sep 2017 03rd Mar to 10th Mar 2018 22nd Dec to 29th Dec 2018 03rd Mar to 07th Mar 2019 27th Oct to 31st Oct 2019 13th Mar to 19th Mar 2023
14 Visual Design	Mr. Ryu Nakagawa, Associate Professor of NCU	17th Sep to 25th Sep 2017 29th Sep to 05th Oct 2018 28th Oct to 02nd Nov 2019 16th Dec to 23rd Dec 2019 04th Nov to 29th Nov 2022 28th Feb to 10th Mar 2023 13th Mar to 20th Mar 2023 7th Apr. to 19th Apr. 2023
15 Seismology	Mr. Takashi Nakata, Professor Emeritus of HU	05th Mar to 12th Mar 2018 15th Sep to 03rd Oct 2019 15th Sep to 11th Oct 2022
16 Seismology	Mr. Yasuhiro Kumahara, Associate Professor of HU	18th Sep to 1st Oct 2019 15th Sep to 11th Oct 2022
17 Seismology	Mr. Takumi Hayashida, Building Research Institute	24th Nov to 02nd Dec 2018 13th Mar to 19th Mar 2023
18 Earthquake Engineering	Mr. Ken Xian Sheng Hao Principal Research Fellow of NIED	21st Sep to 06th Oct 2019 13th May to 21st May 2017
JICA Project Coordinator	Mr. Koichiro Miyara	15 Mar 2021 to 25 Apr 2023
JICA Project Coordinator	Mr. Gaijiro Ando, Director of Ando Consultants Inc.	Apr. 2017 to Mar. 2020

(3) Official visit to Japan

The project funded an official visitto Japan for three Bhutanese members (one from the DoC, one from the DDM, and one from the DES), as shown in Table 1-2.

Table 1-2. Participants in the official visit to Japan

No.	Subject	Term	Travelers	Country
1	To follow up final evaluation	2023 Jan. 1 week	Mr. Sonam Tshewang Mr. Yadav Bal Bhattarai, Mr. Pema	Japan

(4) Short-term trainings in Japan and third-country

The project funded a total of seven short-term trainings in Japan and third-country for twelve Bhutanese members (five from the DGM, three from the DoC, one from the DDM, and one from the DES), as shown in Table 1-3.

Table 1-3. The participants for short-term Training

No.	Subject	Term	Travelers	Country
1	To learn Static jack system	2018 Jan 1 week	Mr. Pema Mr. Lhendup	Japan
2	To learn Micro tremor measurement	2018 Feb. 1 week	Mr. Phutsho Pelgay Ms. Nityam Nepal	Japan
3	To observe earthquake awareness activates in Japan and learn about seismic technologies to mitigate building damage, NCU&NHU	2018 Nov. 1 week	Mr. Yeshey Lotey Mr. Sonam Yangdhen Mr. Kunzang Tenzin	Japan
4	To learn active fault mapping at Hiroshima University	2019 Feb. 2 weeks	Mr. Karma Namgay	Japan
5	International seminar in Kathmandu on Natural disaster in south Asia: interventions, best practices and challenge	2019 Dec. 1 week	DGM	Nepal
6	International academic symposium on active faulting	2020 Jan. 1 week	Dr. Dowchu Drukpa	Japan

7	To exchange seismic observation network operation	2020 Feb. 1 week	Mr. Phutsho Pelgay	Philippine

(5) JICA Knowledge Co-Creation Program in Japan

In total, seven members (two from DES, four from DGM, and one from DDM) took participated in JICA Knowledge Co-Creation Programs as shown in Table 1-4. One counterpart from DES is participating in the training course since October 2022, which is a one-year JICA Program “Seismology, Earthquake Engineering, and Tsunami Disaster Mitigation” to obtain a master’s degree in disaster management. Four more members (one from DES, one from DGM, and two from DoC) took participated in this program as shown in Table 1-5.

Table 1-4. The participants for JICA Knowledge Co-Creation Program in Japan

No.	Subject	Term	Travelers	Country
1	Improvement and disaster prevention of housing and living environment	2017 Sep. 3 months	Mr. Jigme Wangdi	Japan
2	Raising awareness of disaster risk reduction	2018 Jan. 2 months	DDM	Japan
3	Global seismological observation	2018 Jan. 3 months	Mr. Phutsho Pelgay	Japan
4	Disaster risk reduction of buildings	2018 Jun. 1 month	Mr Yeshi Samdrup	Japan
5	Disaster risk reduction of buildings	2019 Jun. 1 month	DES	Japan
6	Global seismological observation	2020 Jan. 3 months	Ms. Nityam Nepal	Japan
7	Global seismological observation	2021 Jan. 3 months	Mr. Karma Namgay	Japan (Remote)

Table 1-5. The participants for Long-term Training (Master course) in Japan

No.	Subject	Term	Travelers	Country
1	Seismology, Earthquake Engineering and Tsunami disaster mitigation, Master's degree course	2019 Sep. 1 year	Mr. Pema	Japan

2	Seismology, Earthquake Engineering and Tsunami disaster mitigation, Master's degree course	2020 Sep. 1 year	Mr. Yadav Lal Bhattarai	Japan
3	Seismology, Earthquake Engineering and Tsunami disaster mitigation, Master's degree course	2020 Sep. 1 year	Ms. Nityam Nepal	Japan
4	Seismology, Earthquake Engineering and Tsunami disaster mitigation, Master's degree course	2021 Sep. 1 year	Mr. Kunzang Tenzin	Japan
5	Seismology, Earthquake Engineering and Tsunami disaster mitigation, Master's degree course	2022 Sep. 1 year	Mr. Tshering Dhendup	Japan

(6) Long-term Training (PhD course) in Japan

One member from the DoC has taken a PhD course at the Graduate School of Design and Architecture at Nagoya City University since September 2017 (Table 1-6). She obtained a doctoral degree in March 2021. Her study theme was the development of seismic technology for composite masonry buildings in Bhutan. She is a scholarship student of the Ministry of Education, Culture, Sports, Science and Technology in Japan (MEXT), selected from the SATREPS slots.

Table 1-6. The participants for Long-term Training (PhD course) in Japan

No.	Subject	Term	Participants
1	Research student / PhD course	3 and half years	Phuntsho Wangmo

A list of training participants' number since April 2017 is shown in Table 1-7.

Table 1-7. Number of training participants

	Short-term training/official visit in Japan or third countries	JICA Knowledge Co-Creation Program	Long-term Training in Japan	Total

DDM	2	1		3
DoC	3	2	1	6
DES	2	4		6
DGM	5	4		9
Total	12	11	1	24

(7) Trainings in Bhutan

In addition to daily on-site training, there were 60 participants trained for advanced techniques in Bhutan as shown in Table 1-8.

Table 1-8. The on-site training course in Bhutan

No.	Name of training course	Period	Participants number
1	Active Fault and Earthquake Disaster Mitigation in Bhutan	2018 Mar 9	Disaster management organizations 20
2	Drones for Disaster Management	2018 May 7	DGM members, Civil engineers 32
3	ICT for operating earthquake monitoring system and its network	2018 Sep 12-13	DGM members
4	Trial Virtual Reality materials	2018 Oct 10	DDM members
5	Microtremor survey	2018 Nov 26 - 30	DGM members 3

(8) Overseas activities cost

As planned, the Japanese side provided about JPY 52 million yen as overseas activities costs.

(9) Procurement of Equipment

The Japanese side purchased equipment of about JPY 186 million yen in total, which include a test facility and test specimens. The details of the equipment are listed on ANNEX 1: List of Products: Equipment (Japan) (Table 1-9).

Table 1-9 List of equipment procured by the project

Item	To	Arrival Dates
1 Materials testing equipment	DoC	Sep. 15, 2017
2 3D laser scanner	DoC	Sep. 19, 2017
3 Vibration table (anchor frame and table)	DoC	Mar. 7, 2018

		Mar. 13, 2019
4 Static jack system	DoC	Mar. 23, 2018
5 Offline earthquake observation equipment	DGM	Oct. 3, 2017 Feb. 27, 2018
6 Telemetry earthquake observation equipment	DGM	Mar. 15, 2018 Jun. 2, 2018
7 Portable array microtremor observation equipment	DGM	Nov. 9, 2018
8 Laser displacement measurement system	DoC	Dec. 11, 2018
9 Acceleration measurement system	DoC	Feb. 26, 2019
10 UAV (drone) for microtopography survey	DGM DDM	Aug. 14, 2019
11 Intensity meters (1st)	DGM	Dec. 11, 2019
12 Intensity meters (2nd)	DGM	Jan. 26, 2020
13 Intensity meters (3rd)	DGM	June 4, 2020
14 Intensity meters (4th)	DGM	Feb. 9, 2021
15 UAV (drone) for microtopography survey	DGM DDM	Mar. 22, 2021
16 Seismometer (1st)	DGM	Mar. 19, 2021
17 Seismometer (2nd)	DGM	Apr. 1, 2021
18 Data logger for offline station	DGM	Mar. 25th 2022
19 Software for seismic data analysis	DGM	Mar. 25th 2022
20 Web camera system for remote seminars and experiments	DoC	Mar. 25th 2022
21 Lap top PC for training program	DES	Apr. 13th 2022
22 VR equipment for dissemination activities	DOC	May 25th 2022
23 VR equipment for dissemination activities	DDM	Apr. 10th 2023

1-2 Input by the Bhutanese side (Planned and Actual)

(1) Counterpart assignment

The following officials have been assigned:

- The Project Director: Director of DDM, MoHCA
- The Project Manager for Output 1: Director of DGM, MoEA
- The Project Manager for Output 2: Director of DoC, MoHCA
- The Project Manager for Output 2: Director of DES, MoWHS
- The Project Manager for Output 3: Director of DDM, MoHCA

Additionally, the following officials worked for the project (approximately 20 persons in total).

- Disaster engineer, DDM
- Architect, DoC
- Engineer, DoC
- Engineer, DES
- Geophysicist, DGM
- Geologist, DGM
- Technician, DGM

Table 1-10 List of the Bhutanese project members (as of March 2023)

Role of the project	Name	Organization
1 Project Director since Aug. 2022	Ms. Nagtsho Dorji	Director of the DoC, Ministry of Home Affairs (MOHA)
Dec. 2021 to Mar. 2022	Mr. Thinlay Wangchuk	Director General of the DDM, Ministry of Home and Cultural Affairs (MOHCA)
Jan.2019 to Nov. 2021	Mr. Jigme Thinlye Namgyal	
Sep. 2017 to Sep. 2018	Mr. Karma Tshering	
Apr. 2017 to Jun. 2017	Mr. Chhador Wangdi	
2 Project Manager	Mr. Yang Dorji	Chief Program Officer, Officiating Director General, DDM
Jul. 2019 to Aug.2022	Mr. Pema Singye	Chief Program Officer, DDM
Apr. 2017 to Jul. 2019	Mr. Tshewang Norbu	Senior Program Officer, DDM
3 Project Manager	Mr. Sonam Tshewang	Executive Engineer, DDM
Apr. 2017 to Dec. 2018	Mr. Yeshey Lotey	Moved to Construction

		Development Board
4 Project Manager	Ms. Pema	Chief Architect, DCHS, Department of Culture, MoHCA
Apr. 2017 to Aug. 2020	Ms. Nagtsho Dorji	Director of the Department of Culture (DoC), MOHCA
5 Working Member	Mr. Pema	Executive Engineer, DoC
6 Working Member (maternity leave)	Dr. Phuntsho Wangmo	Deputy Executive Engineer, DoC
7 Working Member	Mr. Yeshi Samdrup	Executive Architect, DoC
8 Working Member	Mr. Kunzang Tenzin	Engineer, DoC
Apr. 2017 to Feb. 2023	Mr. Ugyen Dorji	Engineer, DoC
9 Support Member	Mr. Dhendup Tshewang	Deputy Executive Engineer, DoC
Apr. 2017 to June. 2022	Mr. Lhendup	Technician, DoC
10 Project Manager	Vacant	Chief Engineer, DES, Ministry of Works and Human Settlement (MOWHS)
Sep. 2018 to Feb. 2023	Mr. Sonam Yangdhen	Leave
Apr. 2017 to Sep. 2018	Mr. Karma Namgyel	Moved to Thimphu Thromde
11 Working Member	Mr. Yadav Lal Bhattarai	Executive Engineer, DES
12 Working Member	Mr. Jigme Wangdi	Deputy Executive Engineer, DES
13 Working Member (Study leave from Oct. '22)	Mr. Tshering Dhendup	Deputy Executive Engineer, DES
14 Support Member	Mr. Bishnu Pradhan	Executive Engineer, DES
15 Project Manager	Dr. Dowchu Drukpa	Specialist (Seismologist), DGM, Ministry of Economic

		Affairs (MOEA)
16 Working Member	Vacant	Officiating Chief, Geologist, DGM
Apr. 2019 to Aug. 2022	Mr. Phuntsho Pelgay	Officiating Chief, Geologist, DGM
Apr. 2017 to Mar. 2019	Mr. Jamyang Chophel	Moved to Punatsangchhu-1 Hydro Power project on secondment
17 Working Member	Ms. Nityam Nepal	Senior Geologist, DGM
18 Working Member	Mr. Karma Namgay	Geologist, DGM
19 Support Member	Mr. Lungten Chedup	Technician, DGM
20 Support Member	Mr. Sonam Tshering	Technician, DGM

(2) Provision of offices, etc.

As planned, the Bhutanese side provided the following:

- Office space
- Test facility land

(3) Other items borne by the counterpart government

N/A

1-3 Activities (Planned and Actual)

For the original plan of operation and actual result of the Project activities, see PO, and major changes in the schedule are summarized as follows.

- Delay in determining the construction site of the test facility as authorized by the Ministry of Home and Cultural Affairs. The construction of the Test facility was started at the end of December 2017 and it was completed in May 2018.

2. Achievements of the Project

2-1 Outputs and indicators

(Target values and actual values achieved at completion)

All the indicators were achieved as described below.

2-1-1 Output 1

Seismic risks of composite masonry buildings are evaluated.

(1) In Output 1-1, Seismic hazard map is used in disaster management plans and contingency plans.

The earthquake source (hypocenter and magnitude) monitoring network and seismic intensity (ground shaking) monitoring network of Bhutan have been installed to enable real-time and long-term hazard assessment. The earthquake source monitoring network consists of 6 online and 3 offline stations which form a total of 17 stations including 8 by RIMES. Two hundred one (201) seismic intensity meters at town offices, in addition to the existing 20 at districts, have been installed and a total of 222 seismic intensity meters are in operation. The first nationwide active fault map of Bhutan was created and published on DGM and DDM web pages. The seismicity map, Seismic Intensity map, and Active fault map are publicized through DGM and DDM web pages. The information provides the public with real-time seismic hazards and will contribute to updating long-term seismic hazard maps in the future.

A seismic hazard map of the M7.8 scenario earthquake along the Main Himalayan Thrust fault in the Bhutan-India border has been created using existing data. A probabilistic macro seismic hazard map of Bhutan with 30 years 50% exceeding probabilities have been created in cooperation with the author of the latest existing hazard map by Stevens (2020). Microtremor surveys of Thimphu, Essuna and Ura have been conducted to find ground motion amplification in local scales. The results from the scenario and probabilistic macro hazard maps and microtremor surveys were combined into micro seismic hazard maps of the three areas, and published through DGM and DDM websites.

The continued microtremor assessments will provide scenarios of the local site conditions which will be incorporated to update hazard maps. These micro seismic hazard and macro seismic hazard maps in the future would provide a more accurate and detailed basis to improve the earthquake contingency and management plans that are in place. Furthermore, the urban development plans are also being reviewed for some of the urban settlements in Bhutan to build resilience and reduce vulnerability among the denser populations.

(2) In Output 1-2, The satisfaction ratings of the users applying the seismic hazard map is 100%.
A scientific seminar on “Seismic hazard/risk assessment of Bhutan” for engineers from various agencies across the country was held on December 19, 2022, at DGM. Basics of seismic hazard assessment, seismicity and earthquake disaster, active fault mapping, ground motion amplification, M7.8 scenario earthquake and strong ground motion, probabilistic seismic hazard, and seismic risk assessment of traditional structures, were presented. The survey questionnaire was shared after the seminar and a 100% satisfaction rating has been achieved.

(3) In Output 1-3, Risk maps in pilot sites have been proposed. Fragility curves and exposure coefficients for each structural type in the pilot site were newly determined based on the literature and the results of this SATREPS project. Microsoft Excel file sheet (with an add-on function to display 3-DMap) for seismic risk calculation and a risk map display program using MATLAB was developed, and both methods were trained and transferred to the technical person in Bhutan with instructional materials and instructional videos.

2-1-2 Output 2
Seismic technology for constructing and strengthening composite masonry buildings is developed. The seismic technology developed by the Project meets the Bhutan seismic standard.

(1) In Output 2-1, to understand the structural characteristics of composite masonry houses in Bhutan, the project has carried out 24-hour microtremor measurement on a rammed earth house and a stone masonry house. By analyzing the data obtained in theproject period, the response of the houses to small-scale earthquakes has been understood. Also, it was found that collected data showed seasonal variations in building responses. Unfortunately, monitoring at the stone masonry house was discontinued in April 2022.

(2) In Output 2-2, to understand the materials used for making rammed earth and stone masonry houses, material tests and core sample tests for compression have been conducted in Bhutan and Japan. Based on these results, the project team developed the methodology how to estimate degree of corrosion of reinforced materials used for strengthening buildings.

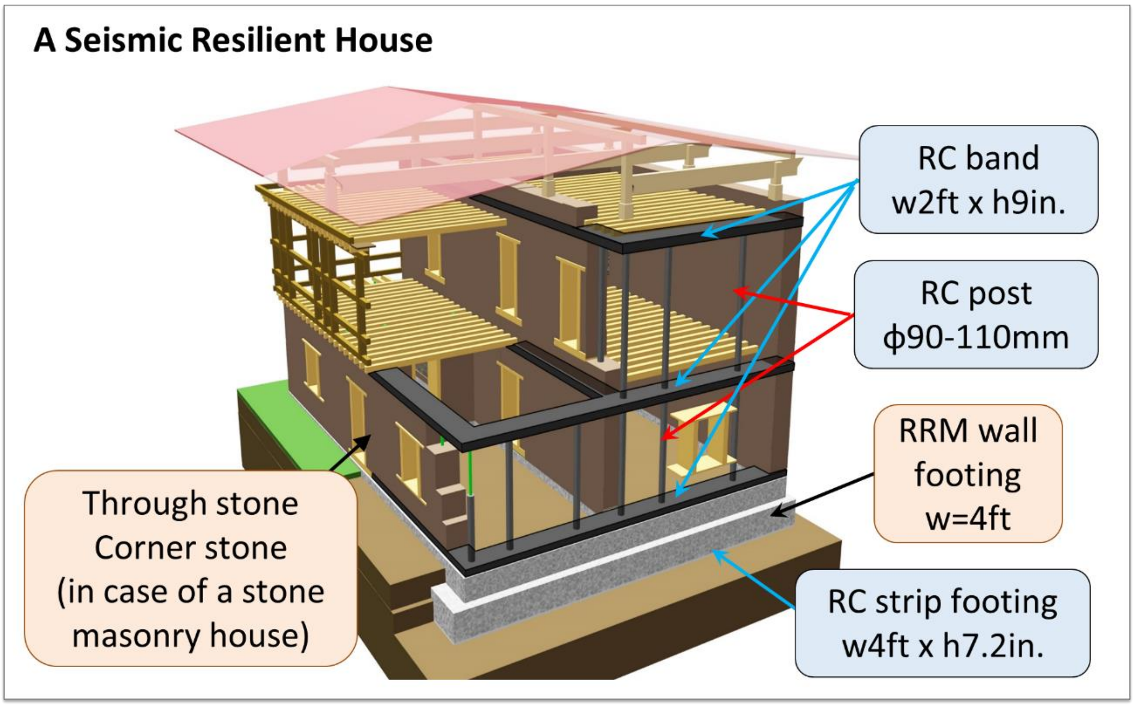
(3) In Output 2-3 and 2-6, since April 2017, the project has undertaken a series of tests on composite masonry structures or buildings made from rammed earth and stones in order to collect evidence for evaluation of the seismic retrofitting techniques. Since December 2018, eight full-scale mock houses and six and eleven small-scale specimens have been tested at the experimental facility, so that the project can design a strengthening technique, such as one with wire meshes, wedges and dowels for exiting houses, and a reinforced concrete horizontal band and post for new construction. In addition, since October 2019, twenty-four dynamic tests by shaking table have been conducted at the experimental facility to grasp the vibration characteristics and the effect of the strengthening technique in both long and short-span directions. In this term, a series of dynamic tests were conducted by the shaking table. The series had rammed earth specimens with/without retrofitting, rammed earth specimens with/without RC posts and bands, stone masonry specimens with/without retrofitting, and stone masonry specimens with/without RC posts and bands. In addition, the direction of the building was changed in the experiment.

(4) In Output 2-4, the structural characteristics and behaviors of composite masonry buildings are analyzed. Finite element modeling to predict the out-of-plane behavior of a typical rammed earth structure is proposed. Both the macro- and micro-modeling strategies adopted finite element (FE) models to simulate the out-of-plane behavior of the rammed earth wall effectively.

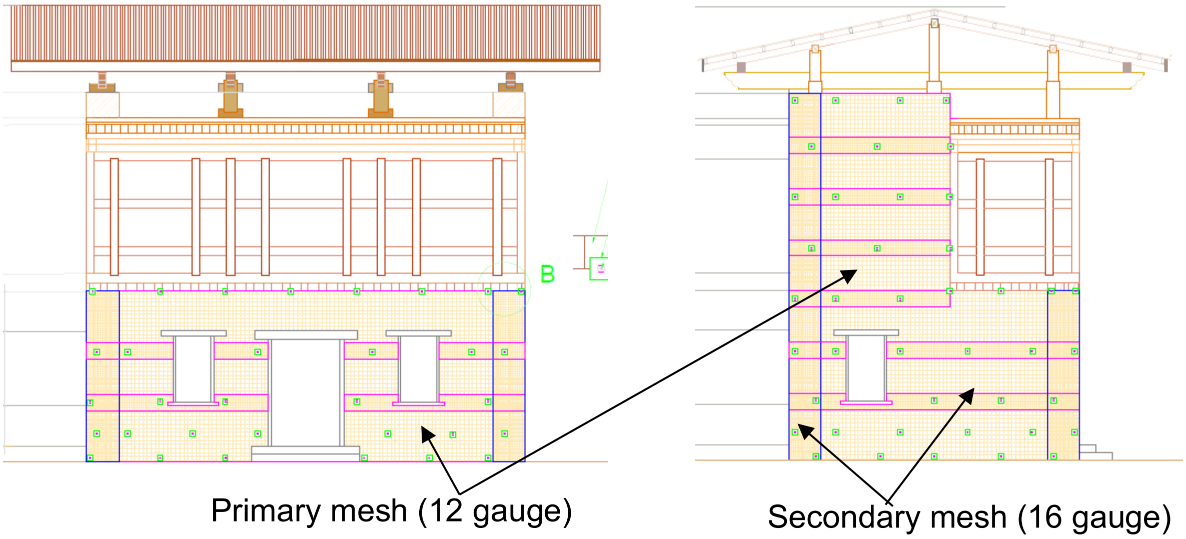
(5) In Output 2-5, a simple method for the seismic evaluation of composite masonry buildings is established. Allowable unit stress calculation has been prepared for the seismic evaluation of structures. If the structure may be assessed to be “Safe - the structure possesses the seismic capacity required against the expected earthquake motions”. Otherwise, the structure should be assessed to be “Unsafe - the structure may collapse against the expected earthquake motions”, in seismic safety. In this case, the seismic reinforcement is required based on the guideline.

(6) In Activity 2-7, the seismic guideline for composite masonry buildings is formulated. Based on the experimental data and analysis results obtained in activities 2-1 to 2-5, the “Manual for Seismic Resilient Construction and

Retrofitting of Rammed earth and Stone masonry Houses" has been developed. The Manual provides the basic knowledge on the seismic resilient structure and also the plans of three model houses whose strength has been evaluated through the structural calculation developed in activity 2-5. The construction process to install the proposed reinforcement measures are described with plenty of illustrations for easier understanding by the users. The retrofitting measures to an existing house are also explained with illustrations. In the case of building a house whose plan is different from the three-model plan, the calculation method is given to analyze the safety of the house.



a. Reinforcement measures for new construction – provide a RC band on every floor level which is one to other connected by RC posts



b. Retrofitting measures to an existing house – wrapping with wire-mesh and cement plaster over the walls from both inside and outside

Fig.2-1. Illustrations for explaining the measures in the Manual

The experimental data and analysis results collected in activities 2-1 to 2-6 are compiled as annexures of the Manual.

(7) In Activity 2-8, the building structural standards of composite masonry buildings to MoWHS for the building permit are proposed. The Department of Culture and Dzongkha Development (the former Department of Culture) and the Department of Infrastructure (the former Department of Engineering Services) prepared draft amendments of the “Earthquake Resistant Construction Training Manual (stone masonry) 2014” by reflecting the contents of the Manual developed in activity 2-7. In the present legal framework in the construction sector, the Bhutan Building Regulation 2018 (BBR2018) and the Bhutan Building Code 2018 (Code2018) regulate the construction in the country, which articles include the procedure of applying and issuing a building permit. As article 4 of the Code 2018 stipulates that the construction of a building of stone masonry must comply with the Training Manual 2014, the amendment of this document is the most simple and appropriate way to reflect the results of the project. Tentatively, the amended version of the document is titled the “National Guidelines for the rammed earth and stone masonry structure”. The draft national guidelines will be reviewed by the Ministry of Infrastructure and Transport (the former Ministry of

Works and Human Settlement) and it is expected to be approved in June 2023. At the same time, it has also been proposed to change article 4 of the Code2018 to specify the new title of the national guidelines.

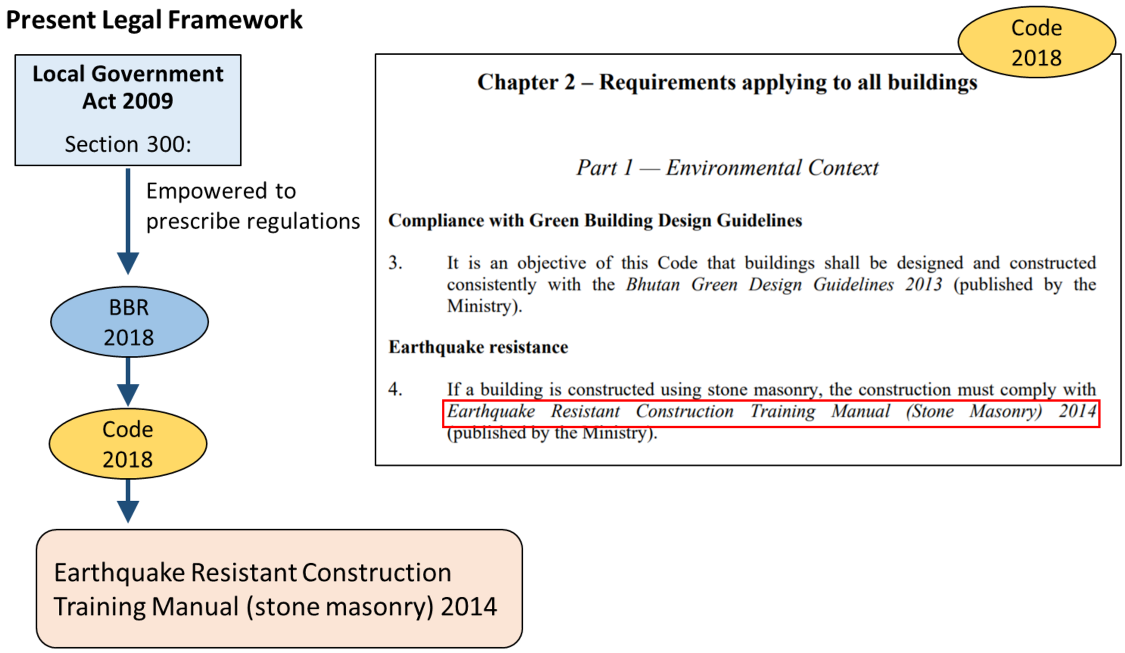


Fig.2-2. Present legal framework in the construction sector

2-1-3 Output 3

The dissemination mechanism for seismic technology is enhanced.

(1) Output 3-1, The budgets for the public awareness program for the general public and the training for local government staff, technical workers, and craftsperson are secured to disseminate the seismic technology across the country. The Department of Infrastructure Development, Ministry of Infrastructure and Transport (the former Department of Engineering Services, Ministry of Works and Human Settlement) has secured BTN. 2.5 million for technical training for the fiscal year 2023 to 2024. This national budget will be used to conduct the ToT and Hands-on training to encourage the engineers and craftsperson to use the reinforcement and retrofitting measures proposed by the project. The Department plans to organize the trainings in the two clusters (the newly introduced cluster system consists of two or three dzongkhag or districts. Nine clusters are formed by 20 districts in the country), one in the western region for the rammed earth

construction and the other in the east region for the stone masonry construction in cooperation with the Department of Culture and Dzongkha Development, Ministry of Home Affairs (the former Department of Culture, Ministry of Home and Cultural Affairs). The Department of Infrastructure Development has a plan to secure the national budget for the continuous years to implement the dissemination plan.

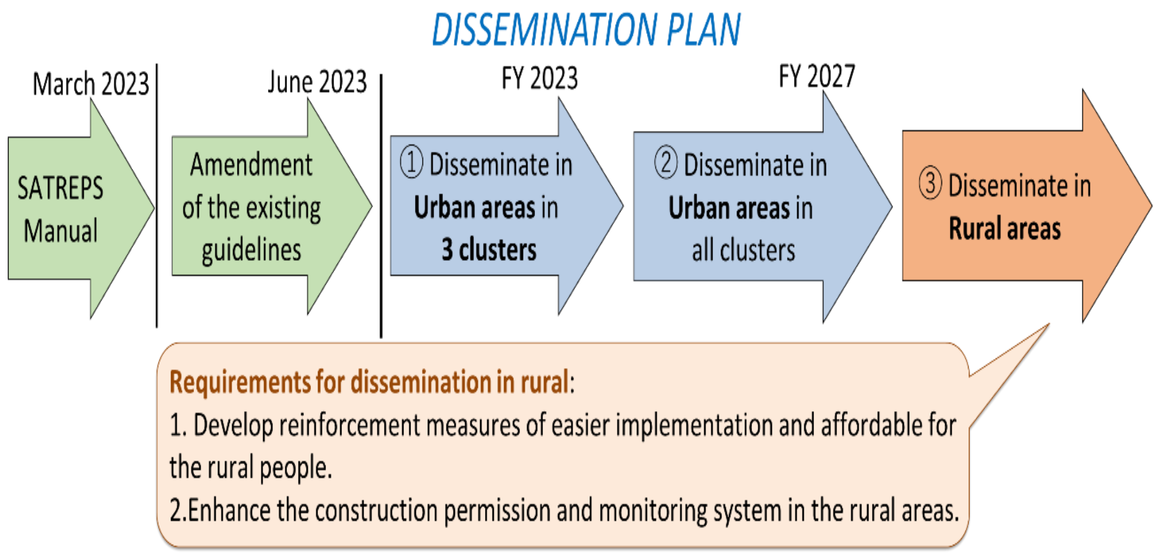


Fig. 3-1. Dissemination plan

In accordance with the dissemination plan which has been developed by the Department of Culture and Dzongkha Development and the Department of Infrastructure Development, the measures are to be disseminated in the urban area of three clusters in the first year after the end of the SATREPS project. Paro cluster in the west, Trongsa in the central, and Trashigang in the east are identified for the initial dissemination. By 2027, the dissemination in all the urban areas shall be completed. The reason why the dissemination targets the urban areas is that those areas have populations who will be able to bear the additional cost of installing the reinforcement measures, and also the mechanism of monitoring the private construction by the municipal offices.

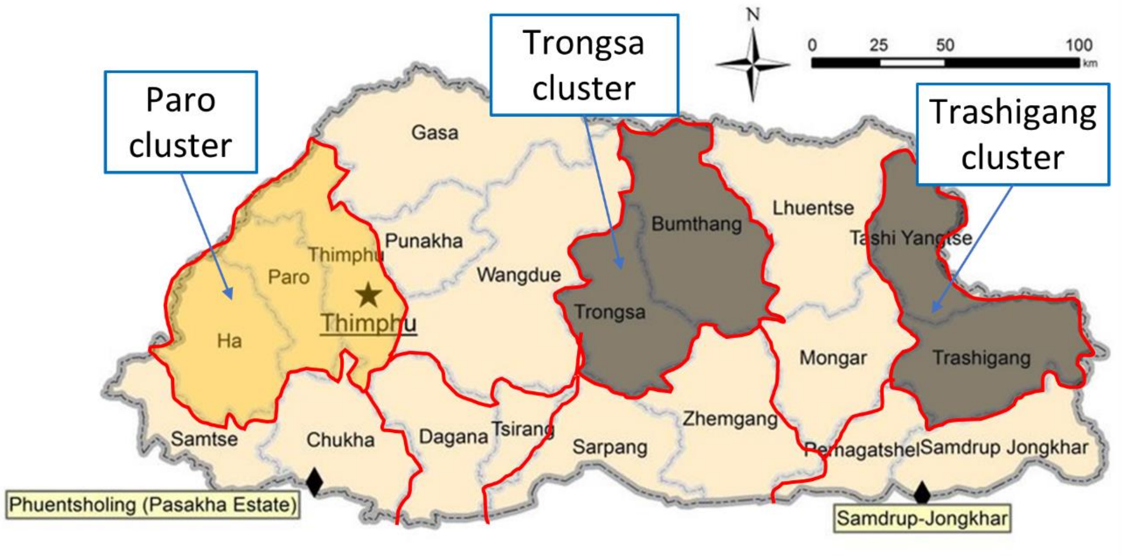


Fig.3-2. Demarcation of the nine clusters (red line), and
the three clusters identified for dissemination in the coming fiscal year

On the other hand, in rural areas, it was found that the majority of the rural population is not able to afford to implement the measures, and there is no mechanism to monitor private construction. The project has developed reinforcement measures whose installation costs do not exceed 20% of the total construction cost at the standard rate. However, such additional cost to install the reinforcements is relatively very high in rural areas, since the cost of building an average-sized house in rural areas is often less than 1/10th of the amount in urban areas. In rural areas, the timber rate is significantly subsidized, and stone and mud are available from the locality. The people often provide labour work to each other. Conversely, the acquisition of the necessary industrial materials such as cement and steel rods costs more in rural areas due to the transportation charge for long distances from commercial areas. Therefore, it is crucial that optional measures that are affordable for the rural population are developed through further research using the test facilities provided by the project. The Department of Culture and Dzongkha Development has already built six specimens to obtain additional data using the remaining amount of the national budget of BTN 9 million secured to carry out the experiments in the SATREPS project period. The Department has also applied to the Ministry of Finance for a budget for the coming fiscal year so that the experiments can continue. Furthermore, the Department of Culture and Dzongkha Development is working on the establishment of a Research Institute for Traditional Structure (RITS). The idea to institute RITS has been conceived before the SATREPS project and discussion with the Royal University of Bhutan (RUB) has been already started. At this time, having the experiment facilities provided and the technical capacity developed in the project, the proposal is seen as more realistic and feasible by the stakeholders.

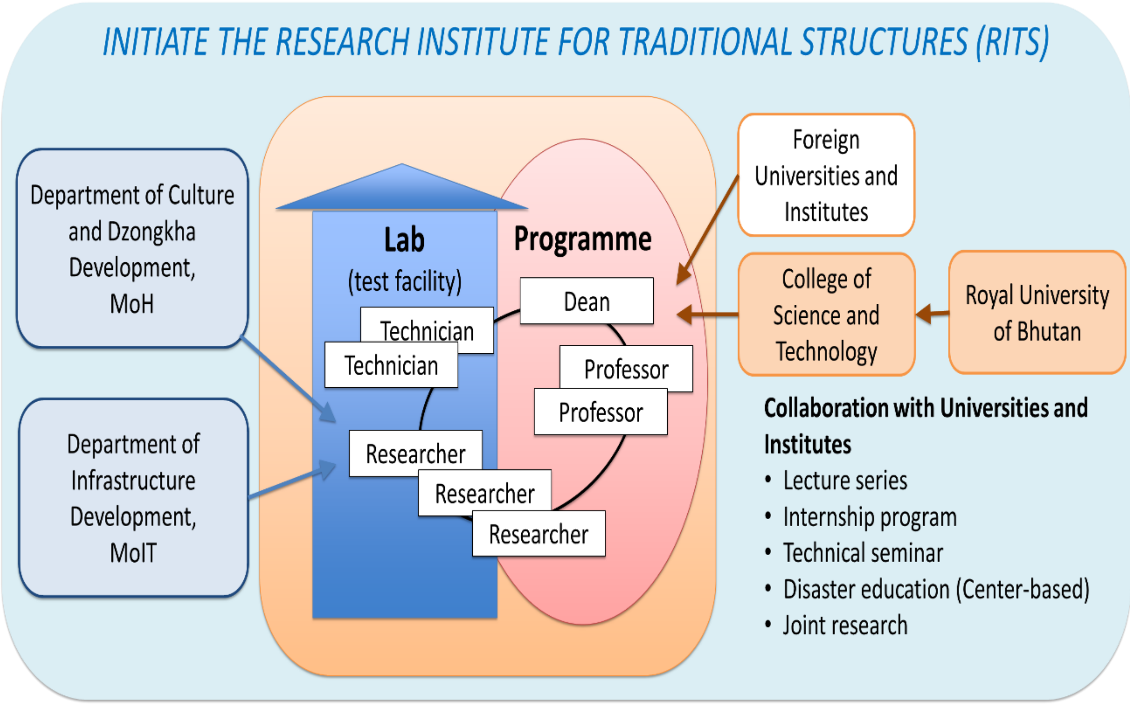


Fig.3-3. Organization chart of RITS proposed by the Department of Culture

The other key issue is about the mechanism for construction monitoring in rural areas. Currently, the gewog office (local government) appraises and approves construction applications submitted by rural residents, which are intended to prevent illegal construction such as encroachments on state-owned land or road. Any technical aspects such as the size, plan, or structure of the building are not subject to review. As the installation of the reinforcement measures into rural construction requires close monitoring by a technical entity to ensure the construction quality which significantly impacts structural strength and durability, a better mechanism of construction approval and monitoring in rural construction is expected. The dissemination plan includes the development and enhancement of the mechanism, taking advantage of the major restructuring of the state and local government administration currently underway.

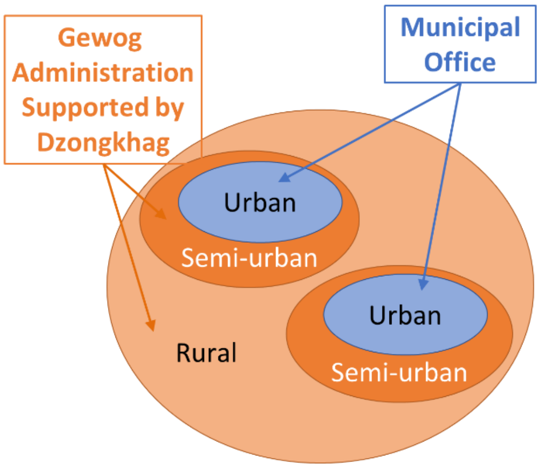


Fig.3-4. regulatory authorities for urban and rural areas

(2) Output 3-2, The satisfaction ratings of the selected national government staff with reference to the contents of the ToT program exceed 90 % on average. In the project, a series of technical training programs were conducted. The participants of the national and district engineers are requested to fill out the feedback form (See annexure). Additionally, during the hands-on training held in Chhumay, feedback from the craftsperson has also collected by interviewing them. The satisfaction ratings of the trainings were found to be between 96% and 100%. The overview of each training program and its satisfaction rating is shown below:

1. ToT held on 12-14 Oct 2021
   (1) Key contents: the structural calculation for seismic reinforcement
   (2) Participants: 10 engineers from 5 districts
   (3) Venue: the conference hall of the Department of Culture

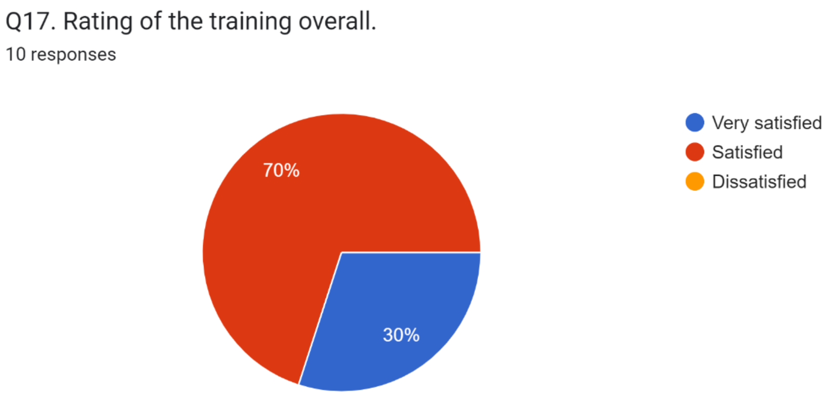


Fig.3-5. satisfaction rate given by the 10 participants

2. ToT held on 8-9 Dec 2022
   (1) Key contents: Outline of the SATREPS project, detailed explanation of the Manual for Seismic Resilient House of Stone Masonry and Rammed Earth, and the hazard and risk map
   (2) Participants: 90 engineers from 10 districts
   (3) Venue: Online

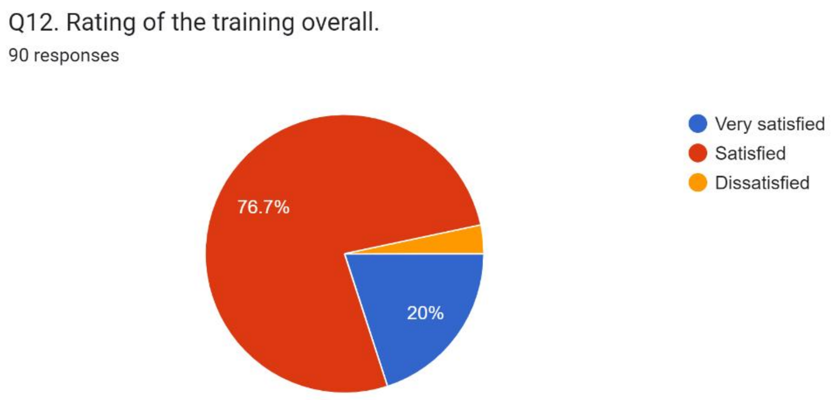


Fig.3-6. satisfaction rate given by the 90 participants

3. Hands-on Training held on 3-4 Nov 2021
   (1) Key contents: Implementation of the retrofit measure on the existing rammed earth house in Dangchu
   (2) Participants: 20 crafts persons and engineers from the western districts
   (3) Venue: Dangchu in Wangduephodrang district

   In this training, filling out the feedback form wasn't requested considering the literacy of the craftsperson.

4. Hands-on Training held on 26-27 Sep 2022
   (1) Key contents: Construction of a rammed earth mock wall with the reinforcement measure
   (2) Participants: 8 crafts persons from Essuna pilot site and 4 engineers from the western districts
   (3) Venue: In DoC compound

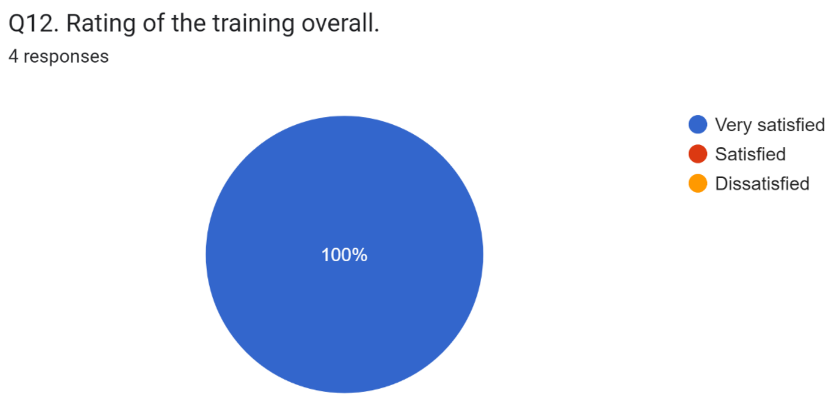


Fig.3-7. satisfaction rate given by the 4 participants (collected feedback from the engineers only due to the literacy of the craftsperson)

5. Hands-on Training held on 29 Nov to 2 Dec 2022
   (1) Key contents: Construction of a stone masonry mock wall with the reinforcement measure and implementation of the retrofit measure on the mock wall built
   (2) Participants: 8 crafts persons from Chhumay and 23 engineers from Bumthang and Monggar districts
   (3) Venue: Chhumay in Bumthang district

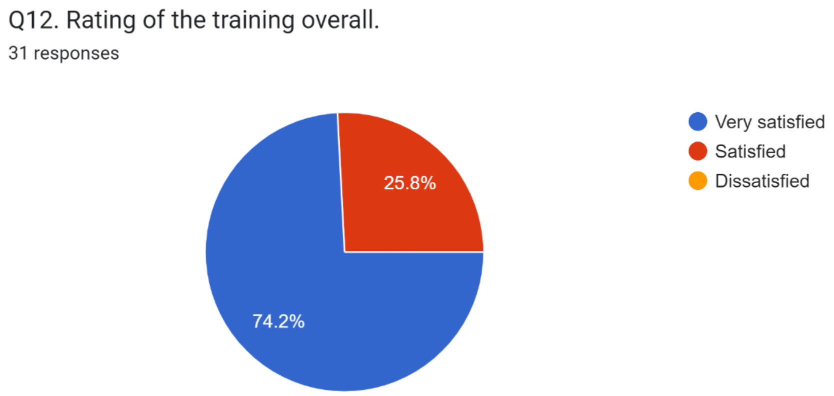


Fig.3-8. satisfaction rate given by the 31 participants (collected feedback also from the craftsperson through the interview using the feedback form)

Fig.3-9. Online ToT (left) and Hands-on Training for retrofitting of Dangchu house (middle) and construction of a rammed earth mock wall (right)

During the above-mentioned programs, several materials which have been prepared for the project were used for easier understanding of the proposed measures. Based on the Manual for Seismic Resilient House of Stone Masonry and Rammed Earth that has been developed as output 2, the following materials are created and unloaded to the websites of the Department of Culture and Dzongkha Development as well as the Department of Infrastructure Development:

(1) Pictogram manuals for rammed earth construction and stone masonry construction both in English and Dzongkha (the national language)
(2) PowerPoint slides on reinforcement measures for new construction as well as retrofitting measures for an existing house
(3) 3D graphics that show the step-by-step process of constructing a typical traditional house with the reinforcement measures
(4) A movie that shows the important construction phases to install reinforcement measures to both rammed earth and stone masonry houses
(5) A movie series developed to introduce the SATREPS projects

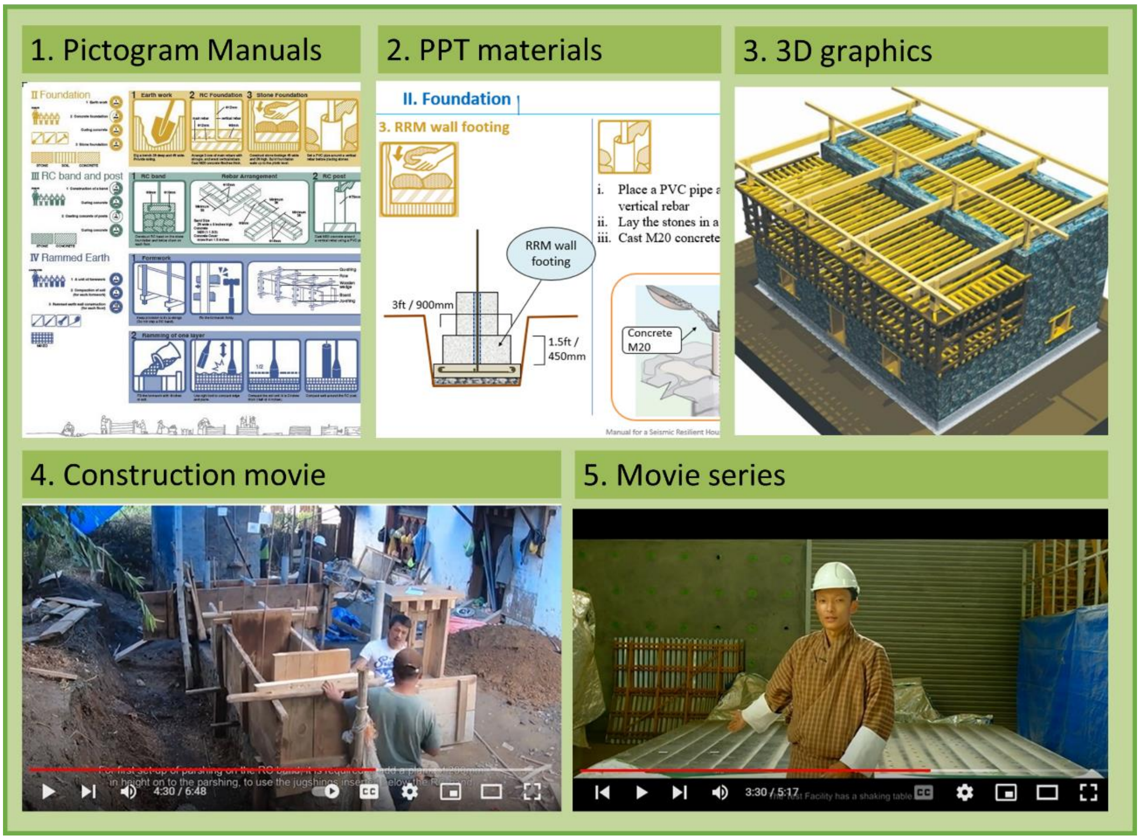


Fig.3-10. Five materials developed for dissemination of the manual

Apart from the above-mentioned technical training, awareness-raising programs for the public were also conducted as below:

6. Public awareness program held on 28 Sep 2022
   (1) Key contents: Basic knowledge of earthquake and disaster mitigation, the outline of seismic resilient house construction, preparation of an evacuation plan
   (2) Participants: 30 residents who represent each household of Essuna village and local government officials
   (3) Venue: Essuna village in Paro district
7. Public awareness program held on 11 Nov 2022
   (1) Key contents: Basic knowledge of earthquake and disaster mitigation, the outline of seismic resilient house construction, SVR experience
   (2) Participants: 50 residents who represent each household of Essuna village and local government officials
   (3) Venue: Ura village in Bumthang district

Fig.3-11. Awareness program in Essuna (left) and Ura (middle and right)

In order to sensitize the importance of disaster preparedness, stimulated virtual reality programs were also created in the project. Depending on the purpose and targets, the following four types of SVR are ready to operate by the Department of Disaster Management and Local Government, Ministry of Home Affairs (the former Department of Disaster Management, Ministry of Home and Cultural Affairs).

(1) SVR-1: a stand-alone system provides an indoor experience of an earthquake
(2) SVR-2: designed to generate earthquakes as one walks around the DoC's test facility and houses built as specimens. Anyone from anywhere can participate in this metaverse.
(3) SVR-3: provides a virtual experience of an earthquake in a rural settlement, the images of which can be linked to the tremor of the shaking table in the test facility.
(4) SVR-4: simulated hands-on experience of the good construction process.

2-2 Project Purpose and indicators
(Target values and actual values achieved at completion)

The project purpose is that "*The capacity of responsible governmental organizations (DDM, DoC, DGM and DES) for seismic disaster mitigation of the composite masonry buildings in Bhutan is enhanced.*" There are two objectively verifiable indicators defined in the PDM. As described below, in consideration of the achievements of Indicators, the Project Purpose was certainly achieved within the Project period based on Project Design Matrix (PDM) version 3.

(1) Indicator 1 is “The responsible governmental organizations provide local government staff as well as technical workers and craftsmen in communities with the proper instructions based on the seismic knowledge”. In terms of the first indicator, since 2017, a total of 20 Bhutanese members from all responsible governmental organizations have attended 16 training programs and a conference held in Japan, related to disaster risk mitigation. The project organized seven local seminars, held in Bhutan, and gathered a total of 80 participants from disaster management sectors. In this term (October 2022-March 2023), Hands-on Training on stone masonry construction (new and retrofitting) was conducted at Chhumey. ToT was held by remote style for engineers of all 20 dzongkhags with the video teaching materials created by the project.

(2) Indicator 2 is “Research results on the seismic technology are accepted and/or published by international and/or local journal(s)”. To achieve the second indicator, the project has published fourteen papers for an international journal, conference and a book.

<u>Publication list:</u>

① Phuntsho Wangmo, Kshitij C. Shrestha, Mitsuhiro Miyamoto, Takayoshi Aoki, “Assessment of out-of-plane behavior of rammed earth walls by pull-down tests”, *International Journal of Architectural Heritage*, 13(2), 273-287, 2018.

② Kshitij C. Shrestha, Takayoshi Aoki, Takaaki Konishi, Mitsuhiro Miyamoto, Jingyo Zhang, Noriyuki Takahashi, Phuntsho Wangmo, Takumi Aramaki, Noboru Yuasa, “Full-Scale Pull-Down Tests on a Two-Storied Rammed Earth Building with Possible Strengthening Interventions”, in: R. Aguilar et al. (Eds.): *Structural Analysis of Historical Constructions*, RILEM Book series, Springer, Cham, 1557-1565, 2019.

③ Pema, Kunzang Tenzin, Kshitij C. Shrestha, Takayoshi Aoki, “Construction Management of Test Facility in Bhutan”, Construction Seminar proceedings “Emerging Trends in the Construction Industry”, Thimphu, Bhutan, 29-30 Aug. 2019.

④ Kshitij C. Shrestha, Takayoshi Aoki, Mitsuhiro Miyamoto, Phuntsho Wangmo, Pema, “In-Plane Shear Resistance between the Rammed Earth Blocks with Simple Interventions: Experimentation and Finite Element Study”, *Buildings*, 10(3), 1-13, 2020.

⑤ Kshitij C. Shrestha, Takayoshi Aoki, Mitsuhiro Miyamoto, Phuntsho Wangmo, Pema, Jingyao Zhang, Noriyuki Takahashi, “Strengthening of Rammed Earth Structures with Simple Interventions”, *Journal of Building Engineering*, 29, 1-10, 2020.

⑥ Pennacchio Roberto, Francesca De Filippi, Maria Bosetti, Takayoshi Aoki, Phuntsho Wangmo, “Influence of Traditional Building Practices in Seismic Vulnerability of Bhutanese Vernacular Rammed Earth Architecture”, *International Journal of Architectural Heritage*, 16(3), 374-393, 2020.

⑦ Phuntsho Wangmo, Kshitij C. Shrestha, Takayoshi Aoki, “Exploratory study of rammed earth walls under static element test”, *Construction and Building Materials*, 266(Part A), 1-23, 2021.

⑧ Phuntsho Wangmo, Kshitij C. Shrestha, Takayoshi Aoki, Mitsuhiro Miyamoto, Pema, “Strengthening strategies for rammed earth wall subjected to out-of-plane loading”, *Civil Engineering*, 1(3), 229-242, 2020.

⑨ Phuntsho Wangmo, Kshitij C. Shrestha, Takayoshi Aoki, Mitsuhiro Miyamoto, Noriyuki Takahashi, Jingyao Zhang, Noboru Yuasa, Sangchul Shin, Pema, Francesca De Filippi, Roberto Pennacchio, “Mesh–Wrap Retrofitting for Rammed Earth Buildings – Test Results of Full–Scale Static Tests”, 17th World Conference on Earthquake Engineering, 17WCEE, Sendai, Japan, 13-18 Sept. 2020. (received 17WCEE Early Career & Student Award)

⑩ Pema, Kshitij C. Shrestha, Takayoshi Aoki, Kunzang Tenzin, Noriyuki Takahashi, Mitsuhiro Miyamoto, Jingyao Zhang, “Test Facility to study Traditional Composite Masonry Structures in Bhutan – An outcome of SATREPS”, 17th World Conference on Earthquake Engineering, 17WCEE, Sendai, Japan, 13-18 Sept. 2020.

⑪ Kshitij C. Shrestha, Takayoshi Aoki, Mitsuhiro Miyamoto, Noriyuki Takahashi, Jingyao Zhang, Phuntsho Wangmo, Noboru Yuasa, Sangchul Shin, Pema, Kunzang Tenzin, “Static Test on Full Scale Rammed Earth Building with Mesh–wrap Retrofitting Strategy”, *Structural Analysis of Historical Constructions*, 1-12, 2021.

⑫ Sayuri Ohashi, Akari Kamiya, Soji Mochizuki, Ken Sonobe, Kaito Kakiuchi, Ryu Nakagawa, Takayoshi Aoki, “SVR-1 (Beta Version): An Educational VR Experience for Earthquake Disaster Mitigation in Bhutan”, International Conference for Asia Digital Art and Design (ADADA+CUMULUS), Malaysia, 26-28 Nov., 2019.

⑬ Phuntsho Wangmo, Kshitij C. Shrestha, Takayoshi Aoki, Pema, Kunzang Tenzin, Ugyen Dorji, “Strengthening techniques for rammed earth buildings: Test results of full-scale static test”, International Conference on Science, Engineering and Technology, ICSciEnTec-2022, Thimphu, Bhutan, 2 May, 2022.

⑭ Roberto Pennacchio, Francesca De Filippi, Takayoshi Aoki, Phuntsho Wangmo, “Appropriate Strengthening Technologies for the Mitigation of Seismic Vulnerability of Bhutanese Vernacular Stone Masonry Architecture”, *International Journal of Architectural Heritage*, 1-26, 2023.

3. History of PDM Modification

Objectively verifiable indicators on the PDM were set by the fourth JCC meeting on 20 December 2019. There was a long period that JP researchers were not able to visit Bhutan due to the COVID-19 impact, the project had an extension, one year. The travel by the JP team resumed in August 2022. Two important assumptions are integral to achieving the project purpose as written in the PDM. The first assumption is that “*The direction of the national policy on seismic disaster management is continuously retained.*” The second is that “*The maintenance costs and staff of the equipment provided are secured by the government of Bhutan.*”

Supplemental indicators and their means of verification were added to the Overall Goals of PDM at the sixth JCC, since the survey conducted by the Output 3 team found the limitation of the gewog offices in terms of the capacity to monitor private constructions using technologies developed by the Project. The national policy, which is written into the 12th Five-Year Plan 2018–2023 by the Gross National Happiness Commission, includes the National Key Result Area (NKRA) “Carbon Neutral, Climate and Disaster Resilient Development”. This policy is the same and seems to be continuously retained.

4. Others

4-1 Results of Environmental and Social Considerations (if applicable)

Due to the COVID-19 pandemic’s impact, there were restrictions in both countries. JP researchers resume their travel from August 2022.

Due to the COVID pandemic project had an extension, of one year. The land secured by DoC for the project experimental facility is the property of DoC, so no resettlement is involved.

4-2 Results of Considerations on Gender/Peace Building/Poverty Reduction, Disability, Disease infection, Social System, Human Wellbeing, Human Right, and Gender Equality (if applicable)

After the global wise COVID-19 pandemic impact, RGoB introduces the Sustainable Development Fee (SDF) for travelers to Bhutan, including official travelers. Budget preparation may not be ready for counterpart institutes since this fee comes up suddenly without detailed notice in advance. In this fiscal year Bhutan counterparts did not have the budget for SDF. However, DoC covered this cost through negotiations with GoB and handling of its own budget and managed to issue visas for JP researchers.

On the way to recovering the economy after the pandemic, views on the consideration of gender and poverty may come up more seriously. It is expected that the project, in its dissemination activities, will consider gender balance along with the gender behavior of recipients. From a poverty reduction perspective, it is expected that the project will contribute to poverty reduction by developing accessible and reasonable seismic technology for composite masonry buildings in which most vulnerable people live.

Due to the slow economic recovery after the pandemic, the number of Bhutanese who prefer to earn in Australia, where wages are high, has increased. Some of the counterparts resigned the civil servant and went to Australia.

III. Results of Joint Review

1. Results of Review based on DAC Evaluation Criteria

1.1 Relevance

The relevance of the Project is evaluated as High.

Before commencing the Project, limited information had been available regarding earthquake monitoring, active faults, and structural characteristics of composite masonry buildings in Bhutan. In particular, after the earthquake in the eastern part of Bhutan in 2009 and the India-Nepal Border earthquake in 2011, many traditional composite masonry buildings were affected by these earthquakes. Nepal was affected by an earthquake in 2015. There was a need for the development of seismic vulnerability assessment and seismic retrofitting methods of composite masonry structures.

Under these situations, the Project could be evaluated as “highly relevant” due to the contribution to the “Disaster Emergency Mobile Communications Network Development Plan” and “Human Resource Development” included in Japan’s Country Assistance Policy to Bhutan.

1.2 Effectiveness

The effectiveness of the Project is evaluated as High.

The outputs and the Project purpose were almost 100% achieved as described in the section of “2. Achievements of the Project”.

Through collaborative research with DDM, DoC, DES and DGM, a total of 14 research papers were published regarding structural characteristics and seismic retrofitting of composite masonry buildings in Bhutan.

The human resource development of counterparts has actively and strongly pushed forward, and the higher level of counterparts’ research activities was achieved in terms of both technology and knowledge. Several young collaborators have already started to plan and conduct their own research projects. The idea to institute RITS (Research Institute for Traditional Structure) was conceived before the SATREPS project and discussion with the Royal University of Bhutan (RUB) has already started. It would be fully expected that the techniques transferred to the counterparts in this Project will spread throughout Bhutan in the near future and the research activities of the RITS will be further strengthened.

1.3 Efficiency

The efficiency of the Project is evaluated as Moderate to High.

Although the Outputs and the Project Purpose were achieved within the Project period, Output 1-1 Enhance the earthquake monitoring network across the country was not achieved due to network problems in Bhutan.

The outage often occurs and results in occasional malfunctions in the laboratory systems and equipment. In particular, lightning strikes occur in the South of Bhutan and result in occasional malfunctions in seismic intensity meters. In the case that repair parts were not available in Bhutan, it took a long time to get things back to normal condition. Since the Project has prepared a stock of possible spare parts throughout the Project period, it is expected to be able to respond flexibly to such problems in the future.

1.4 Impact

The impact of the Project is evaluated as High. The reinforcement and retrofitting technologies developed in the project will contribute to resilient settlement in Bhutan as well as neighboring regions. The level of technical knowledge and experience of the engineers in Bhutan have been highly strengthened.

1.5 Sustainability

The sustainability of the Project is evaluated as Moderate to High. Further research and dissemination programs have been planned to carry out by the counterpart agencies. RITS to be set up will be a center of research projects which facilitates collaborations with technical institutes in and outside of Bhutan.

2. Key Factors Affecting Implementation and Outcomes

Delay in determining the construction site of the test facility as authorized by the Ministry of Home and Cultural Affairs, which delayed the construction of the Test facility.

Due to the COVID-19 pandemic, travel to Bhutan was restricted from March 2020 until August 2022. For almost two and half years, JP researchers could not travel to Bhutan. Consequently, the activities could not be implemented as per the plan. Further, several imposition of lockdown in Bhutan worsen the matter, whereby affecting the construction of test specimens.

3. Evaluation on the results of the Project Risk Management

The covid-19 pandemic affected adversely on the project activities mainly because major activities of the project involved construction of many test specimens. To complete all the planned activities, the project duration was extended by a year, making project duration to 6 years from the initial 5 years. With extension of project duration, all planned activities were completed successfully.

There were several impositions of lockdown and travel restrictions within the country, which consequently affected conducting training of trainers in person. However, it was conducted virtually online, where 95 engineers across the country joined, covering large number of participants which may not have been possible if it was conducted in person.

4. Lessons Learnt

i. Active involvement of local counterparts played a critical role when JP researchers could not travel to Bhutan. For instance, local counterparts carried out full-scale test by themselves with JP researchers guiding virtually.

ii. Online trainings has capable to cover large number of participants with least expenses.

iii. Online videos are effective in dissemination program and it has potential to reach to larger audience.

5. Performance

The overall performance of the project is rated high.

6. Additionality

IV. For the Achievement of Overall Goals after the Project Completion

1. Prospects to achieve Overall Goal

In this Project, the Overall Goals (Seismic technology for disaster mitigation of the composite masonry buildings is disseminated across the country.) are the same as the Project Purpose (The capacity of responsible governmental organizations (DDM, DOC, DGM, and DES) for seismic disaster mitigation of the composite masonry buildings in Bhutan is enhanced) and 4 indicators were set as described above and PO.

The seismic guideline is integrated into the structuring part of the composite masonry buildings in the Bhutan Building Rules (BBR) in June 2023. Research on seismic technology for composite masonry buildings is continued by the responsible government agency. Training and public awareness programs on composite masonry buildings with seismic technology are conducted in 20 dzongkhag. The approval process for new housing construction with the adaptation of seismic technology to composite masonry buildings is improved. Seismic hazard and seismic risk, seismic retrofitting methods, educational materials and public awareness programs developed in this project are expected to become one of the solutions to mitigate the seismic risk of composite masonry structures not only in Bhutan but also in neighbouring countries.

2. Plan of Operation and Implementation Structure of the Bhutanese side to achieve Overall Goal

Because the counterparts acquired enough knowledge of how to conduct seismic hazard and seismic risk, experimental tests and dissemination methods through the Project, continuous research would be implemented by the counterparts of the Project after the Project completion to develop more suitable methods in Bhutan.

In fact, two main collaborators who have been enrolling in the PhD programs and the Master programs through the Project support have continued their own research in terms of seismic retrofitting in Bhutan.

3. Recommendations for the Bhutanese side

The idea to institute RITS (Research Institute for Traditional Structure) was conceived before the SATREPS project and discussion with the Royal University of Bhutan (RUB) has already started. It is highly expected that the counterparts of the Bhutanese government and the RITS appropriately maintain the test facilities as static jacks, vibration table and other equipment which procured by this project. Also, any required technical skills for maintenance were trained by the project.

In expectation of further introduction of the seismic retrofitting methods to the whole of Bhutan, it will be important to continuously train researchers and engineers. For this purpose, continuous human resource development is essential from the viewpoint of the Ministries and research institution RITS.

Countermeasures against seismic vulnerability developed from the results of this Project will be effective to a certain extent in Bhutan, and similar countermeasures will also be effective in neighbouring countries that are threatened by seismic risk similar to Bhutan. These countermeasures will have a broader social impact beyond national borders. It is expected that Bhutan will become a country which actively pushes forward seismic retrofitting on the neighbouring countries.

4. Monitoring Plan from the end of the Project to Ex-post Evaluation

(If the Project will be continuously monitored by JICA after the completion of the Project, mention the plan of post-monitoring here.)

There is no concrete monitoring plan after the end of the project. However, stable and reliable relationships with Bhutanese government staff are established by the project so that continuous scientific discussions are expected.

Also, JICA will continue its commitment to its counterparts in Bhutan by accepting some researchers to Japanese universities to acquire degrees.

ANNEX 1: Results of the Project

(List of Dispatched Experts, List of Counterparts, List of Trainings, etc.)

ANNEX 2: List of Products (Report, Manuals, Handbooks, etc.) Produced by the Project

ANNEX 3: PDM (All versions of PDM)

ANNEX 4: R/D, M/M, Minutes of JCC (copy) (*)

ANNEX 5: Monitoring Sheet (copy) (*)

(Remarks: ANNEX 4 and 5 are internal reference only.)

Separate Volume: Copy of Products Produced by the Project

ANNEX 1 List of Dispatched Experts

Expert	Name, Title, Organization	Duration
1 Chief Advisor/ Masonry Structures	Mr. Takayoshi Aoki, Professor of Nagoya City University (NCU)	13th May to 21st May 2017 14th Sep to 23rd Sep 2017 22nd Dec to 28th Dec 2017 03rd Mar to 10th Mar 2018 07th May to 15th May 2018 04th Aug to 10th Aug 2018 28th Sep to 05th Oct 2018 16th Dec to 30th Dec 2018 26th Feb to 11th Mar 2019 20th Mar to 24th Mar 2019 10th May to 13th May 2019 09th Oct to 23rd Oct 2019 27th Oct to 31st Oct 2019 08th Dec to 23rd Dec 2019 06th Aug to 22nd Aug 2022 17th Sep to 1st Oct 2022 18th Nov to 28th Nov 2022 16th Dec to 31st Dec 2022 27th Feb to 9th Mar 2023 13th Mar to 20th Mar 2023
2 Earthquake Engineering	Mr. Hiroshi Inoue, Principal Research Fellow of the National Research Institute for Earth Science and Disaster Resilience (NIED)	13th May to 20th May 2017 02nd Oct to 15th oct 2017 10th Dec to 16th Dec 2017 04th Mar to 11th mar 2018 17th Mar to 25th Mar 2018 05th May to 13th May 2018 29th Sep to 07th Oct 2018 03rd Mar to 08th Mar 2019 15th Mar to 23rd Mar 2019 10th May to 12th May 2019 28th Sep to 04th Oct 2019 11th Dec to 23rd Dec 2019 25th Jan to 29th Jan 2020 11th Dec to 31st Dec 2022 02nd Mar to 22nd Mar 2023
3 Seismology	Mr. Shiro Ohmi,	14th May to 21st May 2017 02nd Oct to 18th Oct 2017

	Associate Professor of Kyoto University (KU)	03rd Mar to 11th Mar 2018 17th Mar to 30 Mar 2018 08th May to 20th May 2018 10th Sep to 20th Sep 2018 18th Nov to 02nd Dec 2018 24th Feb to 07th Mar 2019 07th May to 20th May 2019 26th Aug to 08th Sep 2019 13th Dec to 22nd Dec 2019 08th Aug to 28th Aug 2022 (18th Mar to 25th Mar 2023)
4 Seismic Engineering	Mr. Noriyuki Takahashi, Associate Professor of Tohoku University (THU)	13th May to20th May 2017 19th Sep to 24th Sep 2017 19th Dec to 24th Dec 2017 16th Dec to 21st Dec 2018 09th May to 13th May 2019 14th Oct to 18th Oct 2019 08th Dec to 12th Dec 2019 17th Sep to 23rd Sep 2022
5 Seismic Engineering	Mr. Mitsuhiro Miyamoto, Associate Professor of Kagawa University (KGU)	13th May to 21st May 2017 17th Sep to 24th Sep 2017 19th Dec to 25th Dec 2017 01st Mar to 10th Mar 2018 04th Aug to 10th Aug 2018 28th Sep to 05th Oct 2018 16th Dec to 30th Dec 2018 26th Feb to 11th Mar 2019 20th Mar to 24th Mar 2019 16th Dec to 30th Dec 2018 02nd Mar to 11th Mar 2019 10th May to 13th May 2019 14th Jul to 18th Jul 2019 09th Oct to 18th Oct 2019 06th Aug to 22nd Aug 2022 19th Sep to 27th Sep 2022 18th Dec to 31st Dec 2022 11th Mar to 20th Mar 2023

6 Building Materials	Mr. Noboru Yuasa, Professor of Nihon University (NU)	14th May to 22nd May 2017 22nd Dec to 27th Dec 2017 20th Dec to 30th Dec 2018 03rd Mar to 11th Mar 2019 14th Nov to 27th Nov 2022
7 Building Materials	Mr. Tomoyuki Koyama, Associate Professor of Kyushu University	14th Nov to 21st Nov 2022
8 Building Materials	Mr. Takumi Aramaki, Assistant Professor of Institute of Technicians	14th May to 22nd May 2017 13th Sep to 30th Sep 2017 15th Dec to 28th Dec 2017 19th Nov to 1st Dec 2022
9 Building Materials	Mr. Sangchul Shin, Post-doctoral researcher of NU	10th Dec to 30th Dec 2018
10 Masonry Structures	Ms. Junko Mukai, Research Assistant Professor of NCU	01st Aug to 31st Aug 2022 19th Sep to 17th Oct 2022 22 Nov 2022 to 15 Jan 2023 28th Feb to 23rd Mar 2023
11 Masonry Structures	Mr. Shrestha Kshitij Charana, Associate Professor of Tribhuvan University	14th May to 21st May 2017 13th Sep to 30th Sep 2017 14th Dec to 27th Dec 2017 21st Feb to 14th Mar 2018 07th May to 15th May 2018 02nd Aug to 10th Aug 2018 26th Sep to 26th Oct 2018 14 Nov 2018 to 24 Jan 2019 18th Feb to 25th Mar 2019 10th May to 24th May 2019 10th Jul t 30th Jul 2019 09th Oct to 31st Oct 2019 06th Dec to 23rd Dec 2019 05th Jan to 07th Jan 2020
12 Structural Engineering	Mr. Jingyao Zhang, Associate Professor of KU	14th May to 20th May 2017 17th Sep to 23 Sep 2017 16th Dec to 21st Dec 2019 19th Dec to 23rd Dec 2019 18th Nov to 28th Nov 2022

13 Graphic Design	Ms. Junko Mori, Professor of NCU	14th May to 21st May 2017 14th Sep to 19th Sep 2017 03rd Mar to 10th Mar 2018 22nd Dec to 29th Dec 2018 03rd Mar to 07th Mar 2019 27th Oct to 31st Oct 2019 13th Mar to 19th Mar 2023
14 Visual Design	Mr. Ryu Nakagawa, Associate Professor of NCU	17th Sep to 25th Sep 2017 29th Sep to 05th Oct 2018 28th Oct to 02nd Nov 2019 16th Dec to 23rd Dec 2019 04th Nov to 29th Nov 2022 28th Feb to 10th Mar 2023 13th Mar to 20th Mar 2023 7th Apr. to 19th Apr. 2023
15 Seismology	Mr. Takashi Nakata, Professor Emeritus of HU	05th Mar to 12th Mar 2018 15th Sep to 03rd Oct 2019 15th Sep to 11th Oct 2022
16 Seismology	Mr. Yasuhiro Kumahara, Associate Professor of HU	18th Sep to 1st Oct 2019 15th Sep to 11th Oct 2022
17 Seismology	Mr. Takumi Hayashida, Building Research Institute	24th Nov to 02nd Dec 2018 13th Mar to 19th Mar 2023
18 Earthquake Engineering	Mr. Ken Xian Sheng Hao Principal Research Fellow of NIED	21st Sep to 06th Oct 2019 13th May to 21st May 2017
JICA Project Coordinator	Mr. Koichiro Miyara	15 Mar 2021 to 25 Apr 2023
JICA Project Coordinator	Mr. Gaijiro Ando, Director of Ando Consultants Inc.	Apr. 2017 to Mar. 2020

Role of the project	Name	Organization
1 Project Director since Aug. 2022	Ms. Nagtsho Dorji	Director of the DOC, Ministry of Home Affairs (MOHA)
Dec. 2021 to Mar. 2022	Mr. Thinlay Wangchuk	Director General of the DDM, Ministry of Home and Cultural Affairs (MOHCA)
Jan.2019 to Nov. 2021	Mr. Jigme Thinlye Namgyal	
Sep. 2017 to Sep. 2018	Mr. Karma Tshering	
Apr. 2017 to Jun. 2017	Mr. Chhador Wangdi	
2 Project Manager	Mr. Yang Dorji	Chief Program Officer, Officiating Director General, DDM
Jul. 2019 to Aug.2022	Mr. Pema Singye	Chief Program Officer, DDM
Apr. 2017 to Jul. 2019	Mr. Tshewang Norbu	Senior Program Officer, DDM
3 Project Manager	Mr. Sonam Tshewang	Executive Engineer, DDM
Apr. 2017 to Dec. 2018	Mr. Yeshey Lotey	Moved to Construction Development Board
4 Project Manager	Ms. Pema	Chief Architect, DCHS, Department of Culture, MoHCA
Apr. 2017 to Aug. 2020	Ms. Nagtsho Dorji	Director of the Department of Culture (DOC), MOHCA
5 Working Member	Mr. Pema	Executive Engineer, DOC
6 Working Member (maternity leave)	Dr. Phuntsho Wangmo	Deputy Executive Engineer, DOC
7 Working Member	Mr. Yeshi Samdrup	Executive Architect, DOC
8 Working Member	Mr. Kunzang Tenzin	Engineer, DOC
Apr. 2017 to Feb. 2023	Mr. Ugyen Dorji	Engineer, DOC
9 Support Member	Mr. Dhendup Tshewang	Deputy Executive Engineer, DOC
Apr. 2017 to June. 2022	Mr. Lhendup	Technician, DOC
10 Project Manager	Vacant	Chief Engineer, DES, Ministry of Works and Human Settlement (MOWHS)
Sep. 2018 to Feb. 2023	Mr. Sonam Yangdhen	Leave

Apr. 2017 to Sep. 2018	Mr. Karma Namgyel	Moved to Thimphu Thromde
11 Working Member	Mr. Yadav Lal Bhattarai	Executive Engineer, DES
12 Working Member	Mr. Jigme Wangdi	Deputy Executive Engineer, DES
13 Working Member (Study leave from Oct. '22)	Mr. Tshering Dhendup	Deputy Executive Engineer, DES
14 Support Member	Mr. Bishnu Pradhan	Executive Engineer, DES
15 Project Manager	Dr. Dowchu Drukpa	Specialist (Seismologist), DGM, Ministry of Economic Affairs (MOEA)
16 Working Member	Vacant	Officiating Chief, Geologist, DGM
Apr. 2019 to Aug. 2022	Mr. Phuntsho Pelgay	Officiating Chief, Geologist, DGM
Apr. 2017 to Mar. 2019	Mr. Jamyang Chophel	Moved to Punatsangchhu-1 Hydro Power project on secondment
17 Working Member	Ms. Nityam Nepal	Senior Geologist, DGM
18 Working Member	Mr. Karma Namgay	Geologist, DGM
19 Support Member	Mr. Lungten Chedup	Technician, DGM
20 Support Member	Mr. Sonam Tshering	Technician, DGM

Item	To	Arrival Dates
1 Materials testing equipment	DoC	Sep. 15, 2017
2 3D laser scanner	DoC	Sep. 19, 2017
3 Vibration table (anchor frame and table)	DoC	Mar. 7, 2018 Mar. 13, 2019
4 Static jack system	DoC	Mar. 23, 2018
5 Offline earthquake observation equipment	DGM	Oct. 3, 2017 Feb. 27, 2018
6 Telemetry earthquake observation equipment	DGM	Mar. 15, 2018 Jun. 2, 2018
7 Portable array microtremor observation equipment	DGM	Nov. 9, 2018
8 Laser displacement measurement system	DoC	Dec. 11, 2018
9 Acceleration measurement system	DoC	Feb. 26, 2019
10 UAV (drone) for microtopography survey	DGM DDM	Aug. 14, 2019
11 Intensity meters (1st)	DGM	Dec. 11, 2019
12 Intensity meters (2nd)	DGM	Jan. 26, 2020
13 Intensity meters (3rd)	DGM	June 4, 2020
14 Intensity meters (4th)	DGM	Feb. 9, 2021
15 UAV (drone) for microtopography survey	DGM DDM	Mar. 22, 2021
16 Seismometer (1^{st})	DGM	Mar. 19, 2021
17 Seismometer (2^{nd})	DGM	Apr. 1, 2021
18 Data logger for offline station	DGM	Mar. 25^{th} 2022
19 Software for seismic data analysis	DGM	Mar. 25^{th} 2022
20 Web camera system for remote seminars and experiments	DoC	Mar. 25^{th} 2022
21 Lap top PC for training program	DES	Apr. 13^{th} 2022
22 VR equipment for dissemination activities	DOC	May 25^{th} 2022
23 VR equipment for dissemination activities	DDM	Apr. 10^{th} 2023

#	Name	Type	Contents
1	Microtremor Survey Basics / Data Processing	Manual	Operation manual of microtremor survey and data processing
2	Introduction to TCP/IP Network - Configure and Manage Network, and Application -	Manual	Manual of Network
3	UNIX 101	Manual	Manual of UNIX
4	Microtremor Survey Basics	Manual	Operation manual of microtremor survey
5	Manual of Static Jack	Manual	Simplified Operation Manual for Loading Experiment with Force Application and Operation Manual of Manual Pump
6	Operation manual	Manual	Operation Manual of Shaking Table
7	Shaking table manual	Manual/ Program	Operation Manual of Shaking Table and data making
8	The Manual for Construction of Rammed Earth	Manual	Construction Manual of Rammed Earth
9	The Manual for Construction of Stone Masonry	Manual	Construction Manual of Stone Masonry
10	Risk map	Program	Program for making Risk map
11	SVR-1	Education Material	Standalone disaster mitigation education material for residents in schools and rural areas
12	SVR-2	Education Material	Standalone disaster mitigation education material using Metaverse
13	SVR-3	Education Material	Disaster mitigation education material in cooperation with shaking table
14	SVR-4	Education Material	Instructional materials for hands-on construction procedures
15	3D graphic video of construction procedures	Education Material	Instructional 3D graphic video for hands-on construction procedures
16	Construction procedure video	Education Material	Construction videos of Rammed Earth, Stone Masonry and Retrofit
17	YouTube	Education Material	YouTube materials of the Project

18	Manual for Seismic Resilient Construction and Retrofitting of Rammed earth and Stone masonry Houses	Manual	Manual for Seismic Resilient Construction and Retrofitting of Rammed earth and Stone masonry Houses
19	Manual for Seismic Resilient Construction and Retrofitting of Rammed earth and Stone masonry Houses Experimental results and data	Manual	Experimental results and data from SATREPS

Attachment 1

Project Design Matrix

Project Title: Project for Evaluation and Mitigation of Seismic Risk for Composite Masonry Buildings in Bhutan — Version No. 0

Target Groups: Engineers/technicians of DDM, DOC, DGM and DES. **Project Period:** April 2017 - March 2022 (Five (5) Years) — Date: 22nd September, 2016

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions	Achievements	Remarks
Overall Goal Seismic technology for disaster mitigation of the composite masonry buildings is disseminated across the country.	1. Seismic guideline is integrated into the structuring part of the composite masonry buildings in the Bhutan Building Rules (BBR). 2. Training and public awareness program on composite masonry buildings with seismic technology are conducted in 20 dzongkhag. 3. Government incentives for composite masonry buildings with seismic technology are established by 2025. 4. The percentage of composite masonry buildings with seismic technology to newly constrcuted ones exceed XX % by 2027.	1. The BBR. 2. Training records. 3. Government incentives. 4. Checklist of the seismic technology attached to the seismic guideline.			
Project Purpose The capacity of responsible governmental organizations (DDM, DOC, DGM, and DES) for seismic disaster mitigation of the composite masonry buildings in Bhutan is enhanced.	1. The responsible governmental organizations provide local government staff as well as technical workers and craftmen in communities with the proper instructions based on the seismic knowledge. 2. Research results on the seismic technology are accepted and/or published by international and/or local jounal(s).	1. Instruction checklist 2. International and/or local jounal(s)	1. The direction of the national policy on seismic disaster management is continuosly retained. 2. The maintencance costs and staff of the equipment provided are secured by the government of Bhutan.	*One article accpeted by an international journal.*	
Outputs 1. Seismic risks of composite masonry buildings are evaluated.	1-1 Seismic hazard map is used in disaster management plans and contingency plans. 1-2 The satisfaction ratings of the users applying the seismic hazard map exceed XX % on avarage. 1-3 Risk maps in pilot sites are proposed.	1-1 Disaster management plans 1-2 Questionnaire survey to the users of seismic hazard map 1-3 Risk maps in pilot sites			
2. Seismic technology for constructing and strengthening composite masonry buildings is developed.	2-1 The seismic technology developed by the Project meets the Bhutan seismic standard.	2-1 Key requirements of composite masonry buildings.			
3. The dissemination mechanism for the seismic technology is enhanced.	3-1 The budgets for the public awareness program for general public and the training for local government staff, technical workers, and craftmen are secured to disseminate the seismic technology across the country. 3-2 The satisfaction ratings of the selected national government staff with reference to the contents of the TOT program exceed XX % on average.	3-1 Budgetary sheets of DDM, DOC, DGM and DES 3-2 Questionnaire survey to the national government staff			

DDM: Department of Disaster Management, Ministry of Home and Cultural Affairs (MoHCA); **DOC**: Department of Culture, MoHCA; **DGM**:Department of Geology and Mines, Ministry of Economic Affairs;
DES: Department of Engineering Services, Ministry of Works and Human Settlement

Attachment 1

Activities	Inputs: Japanese side	Inputs: Bhutanese side	Important Assumptions
1-1 Enhance the earthquake monitoring network across the country. 1-2 Enhance the seismic intensity monitoring network across the country. 1-3 Map ground motion amplifications through micro-tremor obervation and topography survey in pilot sites. 1-4 Prepare a seismic hazard map. 1-5 Examine the vulnerability of the composite masonry buildings through material tests, structural analysis, etc. 1-6 Conduct the risk assessment of seismic disasters in pilot sites. 2-1 Collect the basic data of existing composite masonry buildings through the micro-tremor measurements. 2-2 Conduct the material tests of composite masonry buildings. 2-3 Execute static and dynamic tests for sepcimens of mock buildings with compoiste masonry based on typical Bhutanese houses. 2-4 Analyze the structural characteristics and behaviors of composite masonry buildings. 2-5 Establish a simple method for the seismic evaluation of composite masonry buildings. 2-6 Design the building components for compoiste masonry buildings as standard seismic strengthening kits. 2-7 Formulate the seismic guideline for composite masonry buildings. 2-8 Propose the building structural standards of composite masonry buildings to MoWHS for the building permit. 3-1 Establish the implementation structure to disseminate the seismic technology for composite masonry buildings. 3-2 Develop visual educational materials and public awareness programs based on the developed seismic guideline and hazard map. 3-3 Conduct the training of trainers (TOT) on the seismic guideline for selected national government staff. 3-4 Conduct the training of local government staff, technical workers and craftmen to exercise the seismic guideline in pilot sites. 3-5 Conduct public awareness programs on the seismic guideline for the people of pilot sites.	1. Experts ・Chief Advisor / Masonry Structures ・Earthquake Engineering ・Earthquake Seismology ・Buidling Material and Construction ・Seismic Engineering ・Structural Engineering ・Grapphi and Visual Desing ・Coordinator ・Others as necessary 2. Training of counterpart personel in Japan and/or the Third Country(s) 3. Provision of the machinery and equipment ・Static Jack System ・Vibration Table ・Material Test Equipment ・3D Laser Scanner ・Laser Displacement Measurement System ・Acceleration Measurement System ・Telemetry Earthquake Ovservation Equipment ・Off-line Earthquake Obervation Equipment ・Earthquake Intensitymeter Network Equipment ・Portable Array Microtremor Observation Equipment ・UAV for microtopography survey 4. Local expenses for the project activities as necessary	1. Personnel ・Project Director ・Project Manager ・Counterpart personnel 2. Provision of the project office and facilities necessary for the project implementation 3. Expenses necessary for the project implementation ・Local traveling costs and daily subsistence allowance (DSA) for the counterpart personnel in Bhutan ・Installation, maintenance and operational costs for the machinery and equipment provided ・Others 4. Administrative and operational expenses necessary for the project implementation, such as electricity, water, communication, etc.	1. The engineers/technicians capacitated by the Project continue working for their respective positions. 2. Natural disasters, such as earthquakes, floods, etc., do not have a profound effect on the project activities. **Pre-condition** Understanding and cooperation on the seismic disaster mitigation of composite masonry buildings are obtained from the key stakeholders, such as the DDM, DOC, DGM, DES, etc. ***<Issues and countermeasurs>***

Attachment 1

Project Design Matrix

Project Title: Project for Evaluation and Mitigation of Seismic Risk for Composite Masonry Buildings in Bhutan — Version No. 1

Target Groups: Engineers/technicians of DDM, DOC, DGM and DES. **Project Period:** April 2017 - March 2022 (Five (5) Years) — Date: 20 December 2019

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions	Achievements	Remarks
Overall Goal Seismic technology for disaster mitigation of the composite masonry buildings is disseminated across the country.	1. Seismic guideline is integrated into the structuring part of the composite masonry buildings in the Bhutan Building Rules (BBR). 2. Training and public awareness program on composite masonry buildings with seismic technology are conducted in 20 dzongkhag. 3. Government incentives for composite masonry buildings with seismic technology are established by 2025. 4. The percentage of composite masonry buildings with seismic technology to newly constrcuted ones is 100% by 2027.	1. The BBR. 2. Training records. 3. Government incentives. 4. Checklist of the seismic technology attached to the seismic guideline.			
Project Purpose The capacity of responsible governmental organizations (DDM, DOC, DGM, and DES) for seismic disaster mitigation of the composite masonry buildings in Bhutan is enhanced.	1. The responsible governmental organizations provide local government staff as well as technical workers and craftmen in communities with the proper instructions based on the seismic knowledge. 2. Research results on the seismic technology are accepted and/or published by international and/or local jounal(s).	1. Instruction checklist 2. International and/or local jounal(s)	1. The direction of the national policy on seismic disaster management is continuosly retained. 2. The maintencance costs and staff of the equipment provided are secured by the government of Bhutan.	*One article accpeted by an international journal.*	
Outputs 1. Seismic risks of composite masonry buildings are evaluated.	1-1 Seismic hazard map is used in disaster management plans and contingency plans. 1-2 The satisfaction ratings of the users applying the seismic hazard map is 100%. 1-3 Risk maps in pilot sites are proposed.	1-1 Disaster management plans 1-2 Questionnaire survey to the users of seismic hazard map 1-3 Risk maps in pilot sites			
2. Seismic technology for constructing and strengthening composite masonry buildings is developed.	2-1 The seismic technology developed by the Project meets the Bhutan seismic standard.	2-1 Key requirements of composite masonry buildings.			
3. The dissemination mechanism for the seismic technology is enhanced.	3-1 The budgets for the public awareness program for general public and the training for local government staff, technical workers, and craftmen are secured to disseminate the seismic technology across the country. 3-2 The satisfaction ratings of the selected national government staff with reference to the contents of the TOT program exceed 90 % on average.	3-1 Budgetary sheets of DDM, DOC, DGM and DES 3-2 Questionnaire survey to the national government staff			

DDM: Department of Disaster Management, Ministry of Home and Cultural Affairs (MoHCA); **DOC**: Department of Culture, MoHCA; **DGM**:Department of Geology and Mines, Ministry of Economic Affairs;
DES: Department of Engineering Services, Ministry of Works and Human Settlement

Attachment 1

Activities	Inputs: Japanese side	Inputs: Bhutanese side	Important Assumptions
1-1 Enhance the earthquake monitoring network across the country. 1-2 Enhance the seismic intensity monitoring network across the country. 1-3 Map ground motion amplifications through micro-tremor obervation and topography survey in pilot sites. 1-4 Prepare a seismic hazard map. 1-5 Examine the vulnerability of the composite masonry buildings through material tests, structural analysis, etc. 1-6 Conduct the risk assessment of seismic disasters in pilot sites. 2-1 Collect the basic data of existing composite masonry buildings through the micro-tremor measurements. 2-2 Conduct the material tests of composite masonry buildings. 2-3 Execute static and dynamic tests for sepcimens of mock buildings with compoiste masonry based on typical Bhutanese houses. 2-4 Analyze the structural characteristics and behaviors of composite masonry buildings. 2-5 Establish a simple method for the seismic evaluation of composite masonry buildings. 2-6 Design the building components for compoiste masonry buildings as standard seismic strengthening kits. 2-7 Formulate the seismic guideline for composite masonry buildings. 2-8 Propose the building structural standards of composite masonry buildings to MoWHS for the building permit. 3-1 Establish the implementation structure to disseminate the seismic technology for composite masonry buildings. 3-2 Develop visual educational materials and public awareness programs based on the developed seismic guideline and hazard map. 3-3 Conduct the training of trainers (TOT) on the seismic guideline for selected national government staff. 3-4 Conduct the training of local government staff, technical workers and craftmen to exercise the seismic guideline in pilot sites. 3-5 Conduct public awareness programs on the seismic guideline for the people of pilot sites.	1. Experts ・Chief Advisor / Masonry Structures ・Earthquake Engineering ・Earthquake Seismology ・Buidling Material and Construction ・Seismic Engineering ・Structural Engineering ・Grapphi and Visual Desing ・Coordinator ・Others as necessary 2. Training of counterpart personel in Japan and/or the Third Country(s) 3. Provision of the machinery and equipment ・Static Jack System ・Vibration Table ・Material Test Equipment ・3D Laser Scanner ・Laser Displacement Measurement System ・Acceleration Measurement System ・Telemetry Earthquake Ovservation Equipment ・Off-line Earthquake Obervation Equipment ・Earthquake Intensitymeter Network Equipment ・Portable Array Microtremor Observation Equipment ・UAV for microtopography survey 4. Local expenses for the project activities as necessary	1. Personnel ・Project Director ・Project Manager ・Counterpart personnel 2. Provision of the project office and facilities necessary for the project implementation 3. Expenses necessary for the project implementation ・Local traveling costs and daily subsistence allowance (DSA) for the counterpart personnel in Bhutan ・Installation, maintenance and operational costs for the machinery and equipment provided ・Others 4. Administrative and operational expenses necessary for the project implementation, such as electricity, water, communication, etc.	1. The engineers/technicians capacitated by the Project continue working for their respective positions. 2. Natural disasters, such as earthquakes, floods, etc., do not have a profound effect on the project activities. **Pre-condition** Understanding and cooperation on the seismic disaster mitigation of composite masonry buildings are obtained from the key stakeholders, such as the DDM, DOC, DGM, DES, etc. ***<Issues and countermeasurs>***

Annex 2

Project Design Matrix

Project Title: Project for Evaluation and Mitigation of Seismic Risk for Composite Masonry Buildings in Bhutan

Target Groups: Engineers/technicians of DDM, DOC, DGM and DES.

Project Period: April 2017 - April 2023 (Six (6) Years)

Version No.2

Date: 19 May 2022

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions	Achievements	Remarks
Overall Goal Seismic technology for disaster mitigation of the composite masonry buildings is disseminated across the country.	1. Seismic guideline is integrated into the structuring part of the composite masonry buildings in the Bhutan Building Rules (BBR). 2. Training and public awareness program on composite masonry buildings with seismic technology are conducted in 20 dzongkhag. 3. Government incentives for composite masonry buildings with seismic technology are established by 2025. 4. The percentage of composite masonry buildings with seismic technology to newly constrcuted ones is 95% by 2028.	1. The BBR. 2. Training records. 3. Government incentives. 4. Checklist of the seismic technology attached to the seismic guideline.			
Project Purpose The capacity of responsible governmental organizations (DDM, DOC, DGM, and DES) for seismic disaster mitigation of the composite masonry buildings in Bhutan is enhanced.	1. The responsible governmental organizations provide local government staff as well as technical workers and craftmen in communities with the proper instructions based on the seismic knowledge. 2. Research results on the seismic technology are accepted and/or published by international and/or local jounal(s).	1. Instruction checklist 2. International and/or local jounal(s)	1. The direction of the national policy on seismic disaster management is continuosly retained. 2. The maintencance costs and staff of the equipment provided are secured by the government of Bhutan.		
Outputs 1. Seismic risks of composite masonry buildings are evaluated.	1-1 Seismic hazard map is used in disaster management plans and contingency plans. 1-2 The satisfaction ratings of the users applying the seismic hazard map is 100%. 1-3 Risk maps in pilot sites are proposed.	1-1 Disaster management plans 1-2 Questionnaire survey to the users of seismic hazard map 1-3 Risk maps in pilot sites			
2. Seismic technology for constructing and strengthening composite masonry buildings is developed.	2-1 The seismic technology developed by the Project meets the Bhutan seismic standard.	2-1 Key requirements of composite masonry buildings.			
3. The dissemination mechanism for the seismic technology is enhanced.	3-1 The budgets for the public awareness program for general public and the training for local government staff, technical workers, and craftmen are secured to disseminate the seismic technology across the country. 3-2 The satisfaction ratings of the selected national government staff with reference to the contents of the TOT program exceed 90 % on average.	3-1 Budgetary sheets of DDM, DOC, DGM and DES 3-2 Questionnaire survey to the national government staff			

DDM: Department of Disaster Management, Ministry of Home and Cultural Affairs (MoHCA); **DOC**: Department of Culture, MoHCA; **DGM**:Department of Geology and Mines, Ministry of Economic Affairs;
DES: Department of Engineering Services, Ministry of Works and Human Settlement

Activities	Inputs: Japanese side	Inputs: Bhutanese side	Important Assumptions
1-1 Enhance the earthquake monitoring network across the country. 1-2 Enhance the seismic intensity monitoring network across the country. 1-3 Map ground motion amplifications through micro-tremor obervation and topography survey in pilot sites. 1-4 Prepare a seismic hazard map. 1-5 Examine the vulnerability of the composite masonry buildings through material tests, structural analysis, etc. 1-6 Conduct the risk assessment of seismic disasters in pilot sites. 2-1 Collect the basic data of existing composite masonry buildings through the micro-tremor measurements. 2-2 Conduct the material tests of composite masonry buildings. 2-3 Execute static and dynamic tests for sepcimens of mock buildings with compoiste masonry based on typical Bhutanese houses. 2-4 Analyze the structural characteristics and behaviors of composite masonry buildings. 2-5 Establish a simple method for the seismic evaluation of composite masonry buildings. 2-6 Design the building components for compoiste masonry buildings as standard seismic strengthening kits. 2-7 Formulate the seismic guideline for composite masonry buildings. 2-8 Propose the building structural standards of composite masonry buildings to MoWHS for the building permit. 3-1 Establish the implementation structure to disseminate the seismic technology for composite masonry buildings. 3-2 Develop visual educational materials and public awareness programs based on the developed seismic guideline and hazard map. 3-3 Conduct the training of trainers (TOT) on the seismic guideline for selected national government staff. 3-4 Conduct the training of local government staff, technical workers and craftmen to exercise the seismic guideline in pilot sites. 3-5 Conduct public awareness programs on the seismic guideline for the people of pilot sites.	1. Experts ・ Chief Advisor / Masonry Structures ・ Earthquake Engineering ・ Earthquake Seismology ・ Buidling Material and Construction ・ Seismic Engineering ・ Structural Engineering ・ Grapphi and Visual Desing ・ Coordinator ・ Others as necessary 2. Training of counterpart personel in Japan and/or the Third Country(s) 3. Provision of the machinery and equipment ・ Static Jack System ・ Vibration Table ・ Material Test Equipment ・ 3D Laser Scanner ・ Laser Displacement Measurement System ・ Acceleration Measurement System ・ Telemetry Earthquake Ovservation Equipment ・ Off-line Earthquake Obervation Equipment ・ Earthquake Intensitymeter Network Equipment ・ Portable Array Microtremor Observation Equipment ・ UAV for microtopography survey 4. Local expenses for the project activities as necessary	1. Personnel ・ Project Director ・ Project Manager ・ Counterpart personnel 2. Provision of the project office and facilities necessary for the project implementation 3. Expenses necessary for the project implementation ・ Local traveling costs and daily subsistence allowance (DSA) for the counterpart personnel in Bhutan ・ Installation, maintenance and operational costs for the machinery and equipment provided ・ Others 4. Administrative and operational expenses necessary for the project implementation, such as electricity, water, communication, etc.	1. The engineers/technicians capacitated by the Project continue working for their respective positions. 2. Natural disasters, such as earthquakes, floods, etc., do not have a profound effect on the project activities. **Pre-condition** Understanding and cooperation on the seismic disaster mitigation of composite masonry buildings are obtained from the key stakeholders, such as the DDM, DOC, DGM, DES, etc. ***<Issues and countermeasurs>***

Project Design Matrix

Project Title: Project for Evaluation and Mitigation of Seismic Risk for Composite Masonry Buildings in Bhutan

Version No.3

Target Groups: Engineers/technicians of DDM, DOC, DGM and DES.

Project Period: April 2017 - April 2023 (Six (6) Years)

Date: 29 Sep 2022

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions	Achievements	Remarks
Overall Goal Seismic technology for disaster mitigation of the composite masonry buildings is disseminated across the country.	1. Seismic guideline is integrated into the structuring part of the composite masonry buildings in the Bhutan Building Rules (BBR). Supplemental: (A):Research on seismic technology for composite masonry buildings is continued by the responsible government agency 2. Training and public awareness program on composite masonry buildings with seismic technology are conducted in 20 dzongkhag. 3. Government incentives for composite masonry buildings with seismic technology are established by 2025. 4. The percentage of composite masonry buildings with seismic technology to newly constructed ones is 95% **in city areas** by 2028. Supplemental: (B):Approval process for new housing construction with the adaptation of seismic technology to composite masonry buildings are **improved.**	1. The BBR. Supplmental: (A):Experiments carried out using the test facility 2. Training records. 3. Government incentives. 4. Checklist of the seismic technology attached to the seismic guideline. Supplemental: (B): Legal and /or institutional framework to monitor rural construction			
Project Purpose The capacity of responsible governmental organizations (DDM, DOC, DGM, and DES) for seismic disaster mitigation of the composite masonry buildings in Bhutan is enhanced.	1. The responsible governmental organizations provide local government staff as well as technical workers and craftsmen in communities with the proper instructions based on the seismic knowledge. 2. Research results on the seismic technology are accepted and/or published by international and/or local journal(s).	1. Instruction checklist 2. International and/or local journal(s)	1. The direction of the national policy on seismic disaster management is continuously retained. 2. The maintenance costs and staff of the equipment provided are secured by the government of Bhutan.		
Outputs 1. Seismic risks of composite masonry buildings are evaluated.	1-1 Seismic hazard map is used in disaster management plans and contingency plans. 1-2 The satisfaction ratings of the users applying the seismic hazard map is 100%. 1-3 Risk maps in pilot sites are proposed.	1-1 Disaster management plans 1-2 Questionnaire survey to the users of seismic hazard map 1-3 Risk maps in pilot sites			
2. Seismic technology for constructing and strengthening composite masonry buildings is developed.	2-1 The seismic technology developed by the Project meets the Bhutan seismic standard.	2-1 Key requirements of composite masonry buildings.			
3. The dissemination mechanism for the seismic technology is enhanced.	3-1 The budgets for the public awareness program for general public and the training for local government staff, technical workers, and craftsmen are secured to disseminate the seismic technology across the country. 3-2 The satisfaction ratings of the selected national government staff with reference to the contents of the TOT program exceed 90 % on average.	3-1 Budgetary sheets of DDM, DOC, DGM and DES 3-2 Questionnaire survey to the national government staff			

DDM: Department of Disaster Management, Ministry of Home and Cultural Affairs (MoHCA); **DOC**: Department of Culture, MoHCA; **DGM**:Department of Geology and Mines, Ministry of Economic Affairs;
DES: Department of Engineering Services, Ministry of Works and Human Settlement

Annex 2

Activities	Inputs: Japanese side	Inputs: Bhutanese side	Important Assumptions
1-1 Enhance the earthquake monitoring network across the country. 1-2 Enhance the seismic intensity monitoring network across the country. 1-3 Map ground motion amplifications through micro-tremor observation and topography survey in pilot sites. 1-4 Prepare a seismic hazard map. 1-5 Examine the vulnerability of the composite masonry buildings through material tests, structural analysis, etc. 1-6 Conduct the risk assessment of seismic disasters in pilot sites. 2-1 Collect the basic data of existing composite masonry buildings through the micro-tremor measurements. 2-2 Conduct the material tests of composite masonry buildings. 2-3 Execute static and dynamic tests for specimens of mock buildings with composite masonry based on typical Bhutanese houses. 2-4 Analyse the structural characteristics and behaviours of composite masonry buildings. 2-5 Establish a simple method for the seismic evaluation of composite masonry buildings. 2-6 Design the building components for composite masonry buildings as standard seismic strengthening kits. 2-7 Formulate the seismic guideline for composite masonry buildings. 2-8 Propose the building structural standards of composite masonry buildings to MoWHS for the building permit. 3-1 Establish the implementation structure to disseminate the seismic technology for composite masonry buildings. 3-2 Develop visual educational materials and public awareness programs based on the developed seismic guideline and hazard map. 3-3 Conduct the training of trainers (TOT) on the seismic guideline for selected national government staff. 3-4 Conduct the training of local government staff, technical workers and craftsmen to exercise the seismic guideline in pilot sites. 3-5 Conduct public awareness programs on the seismic guideline for the people of pilot sites.	1. Experts ・Chief Advisor / Masonry Structures ・Earthquake Engineering ・Earthquake Seismology ・Building Material and Construction ・Seismic Engineering ・Structural Engineering ・Graphic and Visual Design ・Coordinator ・Others as necessary 2. Training of counterpart personnel in Japan and/or the Third 3. Provision of the machinery and equipment ・Static Jack System ・Vibration Table ・Material Test Equipment ・3D Laser Scanner ・Laser Displacement Measurement System ・Acceleration Measurement System ・Telemetry Earthquake Observation Equipment ・Off-line Earthquake Observation Equipment ・Earthquake Intensity meter Network Equipment ・Portable Array Microtremor Observation Equipment ・UAV for microtopography survey 4. Local expenses for the project activities as necessary	1. Personnel ・Project Director ・Project Manager ・Counterpart personnel 2. Provision of the project office and facilities necessary for the project implementation 3. Expenses necessary for the project implementation ・Local traveling costs and daily subsistence allowance (DSA) for the counterpart personnel in Bhutan ・Installation, maintenance and operational costs for the machinery and equipment provided ・Others 4. Administrative and operational expenses necessary for the project implementation, such as electricity, water, communication, etc.	1. The engineers/technicians capacitated by the Project continue working for their respective positions. 2. Natural disasters, such as earthquakes, floods, etc., do not have a profound effect on the project activities. **Pre-condition** Understanding and cooperation on the seismic disaster mitigation of composite masonry buildings are obtained from the key stakeholders, such as the DDM, DOC, DGM, DES, etc. ***<Issues and countermeasures>***