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PRIMARY RESEARCH

The practice of design-build programs in remote areas in Taiwan

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Abstract
This study analyzed the design-build programs promoted by the Association of Humanitarian Architecture (AHA) in Taiwan in the last four years using participant observation combined with secondary qualitative study and documentation. Then, it used the Collaborative Construction Model established in the previous research for comparison. The objective is to provide international organizations planning to enter Asia-Pacific for collaborative construction with a comprehensive recommendation. We found that the participants in the cases built explicit knowledge by reading the construction manuals and then gained tacit knowledge from the local professionals and vocational-school teachers within subdivided learning and processing lines. The outcome demonstrated that such an approach allowed the participants with different backgrounds to work together effectively and leveraged the smaller number of on-site professionals. By using the natives' tacit knowledge about their environment and local materials for collaborative construction, the participants experienced unexpected results and joys. It is common for Austronesian and agricultural residents to have constructional skills as their second professional specialty. The use of local professionals' tacit knowledge to guide the participants during construction led to increased self-confidence and honor in the local professionals. Besides, by combining traditional and modern constructional methods, the dependency on industrialized products in remote areas could be reduced instead of using the simple construction system utilized in urban areas.

INTRODUCTION

Due to the emergence of the ideological trend of critical regionalism, social architecture, community architecture, open-source culture, the field of architecture has recently seen a shift from large-scale or mass development projects to cooperation between people and communities. Meanwhile, with the provision of de-professionalized design drawings for public use by architectural professionals and the wide propagation of constructional knowledge, along with the advancement of the maker movement, we are seeing more and more crowd-collaborative construction projects being developed. However, there remain many unrecognized concepts, skills, and risks in collaborative construction. Thus, the ability to achieve creative collaboration between local professionals and foreign volunteers, to pass on solid knowledge, and to provide relevant contents within limited construction budgets is essential for collaborative construction projects to meet their goals, allowing the participants to learn how to conduct their work better.

Taiwan is an island country with 58%, 29%, and 13% of its territory covered by forests, agricultural lands, and cities, respectively. As to the composition of its population, in addition to Han, 2.37% of its people are Austronesian aborigine, 15% are Hakka (Suharti & Pramono, 2016; Yuan, 2018), while most of the population is distributed across the non-urban lands, representing 87% (Ameer, 2017; Yuan, 2018). Similar to the situation in other island countries in Southeast Asia and the Pacific Ocean, geographic limitations have brought about an urban-rural gap. Constructions in remote areas mainly involve natural materials and light tools. This study analyzed the design-build programs promoted by the AHA, National Chiao Tung University (NCTU), and National Cheng Kung University (NCKU) in Taiwan in the last four years using participant observation combined with

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secondary qualitative study and documentation. Then, we used the collaborative construction model established in the previous research for comparison. Our objective is to provide international humanitarian organizations that are planning to enter Asia-Pacific for collaborative construction with a comprehensive recommendation.

The six cases investigated in this study had the following traits in common: 1. the design phase was completed in universities; 2. the construction was performed according to the normalized construction manual; and 3. no limitation was placed on the ratio between paraprofessionals and non-professionals as the participants. The six cases can be divided into two types: designed for university courses and designed for university labs. The first type was referred to as course cases, and was jointly conducted by NCTU and AHA. These one-semester courses lasted for five months or 18 weeks, wherein three hours were spent in each of the first 17 weeks for design development, and the last week was for on-site construction. These course cases were CASE-C1, Bamboo Tectonic; CASE-C2, Smart Greenhouse; and CASE-C3, Tea Showroom. The second type was referred to as non-course cases, being the cooperative projects of NCTU, NCKU, and AHA. For these projects, NCTU's HA Lab and NCKU's CODE Lab developed the designs. There were no classroom courses given. Instead, construction manuals were released before the commencement of construction activities, which lasted for three to nine days at the construction sites. These cases were CASE-NC1, WikiHouse; CASE-NC2, Wooden Pavilion; and CASE-NC3, Wooden Watchtower.

We found that the participants in the six cases built explicit knowledge by reading the construction manuals, and then gained tacit knowledge from the local professionals and vocational-school teachers within subdivided processing lines. The outcome demonstrated that such an approach allowed the participants with different backgrounds work together on collaborative construction effectively, and leveraged the smaller number of on-site professionals.

We also found that by making good use of the native's tacit knowledge about their environment and local materials for collaborative construction, the participants experienced unexpected results and joys. It is common for Austronesian tribes and the agricultural residents of rural villages to have constructional skills as their second professional specialty. We can also confirm that the use of local professionals' tacit knowledge to guide the participants during construction led to the increase of self-confidence and honor in the local professionals. Besides, by combining local and traditional constructional methods with modern constructional methods, instead of using the simple construction system utilized in urban areas, the dependency on industrialized construction products in remote areas could be reduced.

LITERATURE REVIEW

In the Western world, design-build programs have been notably popularized among universities in the last two decades. The related research field covers four segments: 1. Architecture learning: hands-on experience is accumulated through classroom courses and learning by building outside of the schools, so that students can interact more with the industry in the real world and acquire pragmatic abilities (Boyer & Mitgang, 1996; Niamhom, Srisuantang, & Tanpichai, 2018). In some programs, construction sites in local communities are also used as classrooms for the students to explore various architectural practices and satisfy both their social and architectural learning needs (Corser & Gore, 2009; Gatpandan & Ambat, 2017); 2. Cognitive psychology: the impact of hands-on learning on architectural creativity is investigated (Carlson & Sullivan, 1999); 3. Tectonic: digital fabrication is used, for example, for community reconstruction after Hurricane Katrina (Arsal & Ambarwati, 2018; Piroozfar & Piller, 2013); and 4. Sociology: co-creation is achieved through daily engagement in local communities (Wates & Knevitt, 2013), and humanitarian architecture is realized through the collaboration between architects and universities based on social architecture (Charlesworth, 2014).

The design-build programs provided in the Asian-Pacific region in the last decade can be divided into two groups. The first is in the form of courses or research projects initiated by universities, where the students are sent to some rural villages in China to talk to agricultural people and develop a series of construction designs, such as those conducted by HKU's Rural Urban Lab (Bolchover & Lin, 2013) and CUHK's School of Architecture (Wang & Crolla, 2017). As another example, Singapore Polytechnic works with international organizations to provide programs on humanitarian affairs in their School of Architecture & the Built Environment, through which the students go to Cambodia to participate in on-site lavatory design-build programs (Chee, Cheng, & Ng, 2014). The architect team of the University of New South Wales in Australia use digital tools to perform the digital fabrication of lavatories in the Solomon Islands (Yeung & Harkins, 2011). The second group of design-build programs provided in the Asian-Pacific region involves bottom-up crowd collaboration promoted by architects. For instance, Patama Roonrakwit, a Thai architect, built a post-tsunami shelter for people in Phang

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Nga Province in the southern part of Thailand (Hamdi, 2013), whereas Hsieh Ying-chun, an architect form Taiwan, designed post-tsunami emergency housing (Charlesworth, 2014). The more iconic examples involve two Japanese Pritzker-winning architects, Shigeru Ban and Toyo Ito. The former is devoted to the reformation of refugee camps in war-affected areas worldwide and of living environments in shantytowns in the third world, and to the teaching of refugees and disaster victims regarding the maintenance of living quality with simple skills (Jacobson, Bruderlein, Pollock, Weizman, & Ban, 2014). The latter entered disaster areas desolated by the 2011 Tōhoku Earthquake to help affected people rebuild their homes (Peltason & Yan, 2017).

The design-build programs provided in the Asian-Pacific area, whether developed by universities or by architect teams, mostly focus on regional materials and special construction methods, with less attention paid to collaboration between local and foreign volunteers. While there have been many theories about design-build programs developed in the Western world, it is questionable whether these theories can be directly applied to the Asian-Pacific area where the customs and conditions are different from those of Western countries. Therefore, this study investigated the design-build programs held jointly by a humanitarian architecture organization and some universities in Taiwan with the goal of providing guidance that helps international humanitarian organizations to drive crowd-collaborative construction projects in the Asian-Pacific area.

METHODOLOGY

Participants

Some architectural professionals specialize in design, while others specialize in construction (Alexander, Davis, Martinez, & Corner, 1985). In this study, the design professionals were three professors from NCTU and NCKU with 10 respective years of experience in teaching design, while the construction professionals were six master workers with 10 respective years of experience in construction practices, including an on-site agricultural worker, a bamboo handicraftsman, an architect, a woodworking teacher in a vocational school, a lacquer tutor, and a blacksmith. The participants of this study were mainly professionals, paraprofessionals, and non-professionals working in the construction sites of the six cases. The counts of the Participants in respective cases are shown in Table 1.

TABLE 1. The counts of the Participants in six cases

Case Number	Professional	Paraprofessional	Non-Professional	Total
C1	2	5	8	15
C2	2	5	17	24
C3	3	7	15	25
NC1	2	7	4	13
NC2	3	15	23	41
NC3	2	7	6	15

The samples were collected from two sources. The first included the students participating in NCTU's program of Smart Living & Humanitarian Fieldworks, some constructional professionals invited by the teachers of the program, agricultural people, and the volunteers recruited by AHA. The second included the design teams from NCTU's HA Lab and NCKU's CODE Lab, as well as the teachers and students from the Department of Architecture Technique, Taipei Municipal Da-An Vocational High School, together with the blacksmiths invited by the co-organizing elementary school, the students' parents, and the volunteers recruited by AHA. The subjects were mainly obtained in three ways: 1. screening of the candidates who were paraprofessionals and non-professionals, such as students and volunteers, through interviews; 2. invitation of construction professionals by design professionals; and 3. invitation of local professionals and non-professionals in the field of construction by the natives.

Research Tools

six cases through participant observation, with the daily activities truthfully logged. Upon the completion of construction, data were extracted using the method of multiple case research from the reports of the six cases and AHA's official website. Then the cases were analyzed through secondary qualitative study, and the data archived in AHA's tool library

were directly used according to documentation. Lastly, the framework of the Collaborative Construction Model identified in the previous research was used for comparative analysis. The research tools are shown in Table 2.

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TABLE 2. The research tools in six cases

Methodology	Research Tools	Source
Participant Observation	Construction logs	This study
Secondary Qualitative Study	Reports of service and learning results	NCTU's Service-Learning Center
	Reports of sponsoring results	AHA
	Portfolio on AHA's official website	http://www.aha.tw/
Documentation	Records of tool lending and returning	AHA's Tool Library
Model Method	Collaborative Construction Model	This previous research

Method and Process for Data Collection

Construction logs

The following items of information were created using direct observation as a primary data-gathering device and descriptive observation: events, time, and division of labor.

Reports of service and learning results

These reports were spontaneously made by the course participants after the completion of construction, and presented as the service and learning results of NCTU. The contents included course outlines and schedules, introduction of participating teams and instructors, procedures of workshops, photos, information of tools and materials, individual groups' design works, and participant's experience sharing.

Reports of sponsoring results

AHA compiled the outcomes of projects from design to construction for the record of relevant sponsors. The contents included introduction of the participating instructors, photos, information of tools and materials, design development, and so on. This study extracted the following items from the preceding two types of reports: manpower, materials, tools, collaboration in construction, and collaboration in living.

Portfolio on AHA's official website

The contents were provided by the design teams, construction teams, and local participants of AHA to be published on its official website (Association of Humanitarian Architecture, 2018); They included backgrounds and concepts of designs, locations, construction time, and information of design teams, construction teams, partner organizations, craftsmen, consultants, and volunteers. This study extracted the following items from these records: manpower and collaboration in construction.

Records of tool lending and returning

These records included requests for lending tools submitted to AHA's tool library by the construction teams before the commencement of construction. This study extracted the following items from these records: tool lists and damage records. The information are shown in Table 3.

TABLE 3. The research tools in six cases

Case Number	Construction Logs	Reports of Service and Learning Results	Reports of Sponsoring Results	AHA's Official Website	Records of Tool
C1	★	△		▲	●
C2	★	▲		▲	●
C3	☆	▲		▲	●
NC1	★		▲	▲	●
NC2	☆		▲	▲	●
NC3	★		▲	▲	●

★ Participant Observation; ▲ Secondary Qualitative Study; ● Documentation ☆ △ the data were incomplete

Models

According to the results of previous researches, an open source model for collaborative construction was proposed using the model method by conducting a literature review, historic research, and ethnography.

Processing and Analysis of Data

Construction logs

The records were analyzed to identify the natural and human factors. This study classified the human factors into five groups: unfamiliarity with construction methods, overload, faulty fabrication, on-site troubleshooting, and material supplement. Since some of the daily records were incomplete, this study also referred to meeting minutes, timelapse photography (Figure 1), and everyday work photos Figure 2) , participants' experience sharing (Figure 3). Discussions with witness participants were also conducted for better data recognition.

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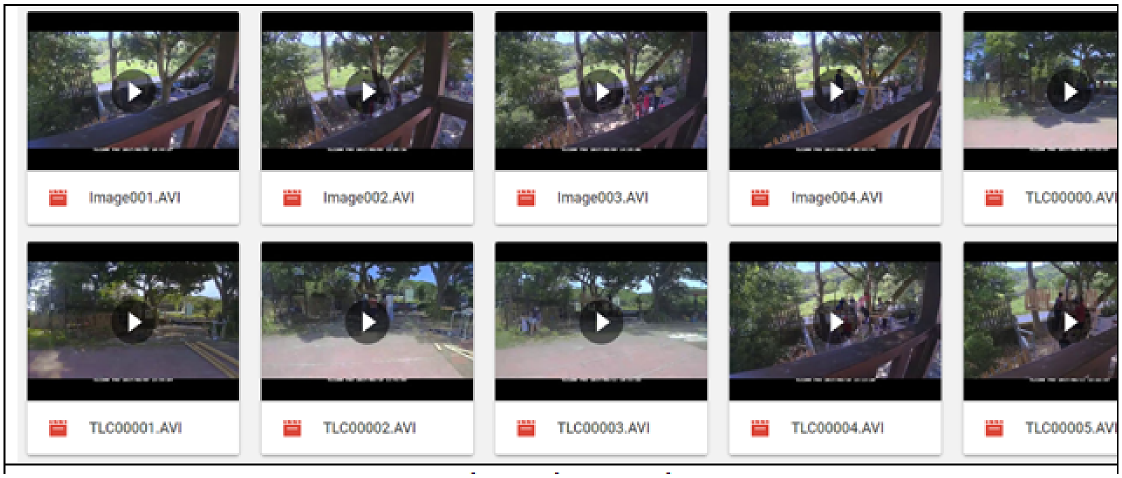

FIGURE 1. CASE-NC3 Time-lapse photography in Aug. 9-11, 2017 (Source: https://goo.gl/nMq8Ed)

FIGURE 2. CASE-C2 daily photos in Jan. 18-23, 2016 (Source: https://goo.gl/U1ymeG)

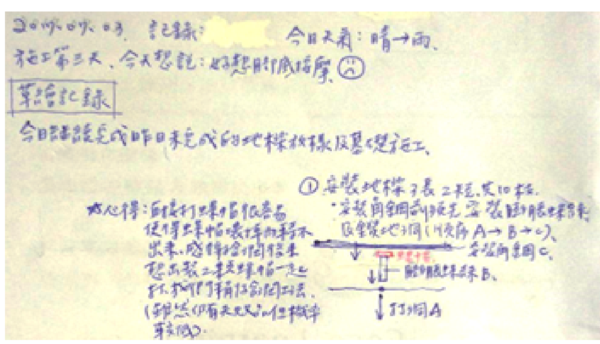

FIGURE 3. CASE-NC2 participant's note on Jul. 3, 2017 (Source: https://goo.gl/6n8Lep)

Reports of service and learning results/reports of sponsoring results

For the classification of manpower, professional levels were considered. In terms of collaborative construction, on-site and off-site constructional teams were differentiated, and six working items were identified: foundation, masonry, carpentry, bamboo handicrafts, lacquer works, and blacksmith works. In terms of collaborative living, workers native to the relevant community and workers coming from outside were differentiated, and divisions among volunteers, commensal workers, and hired workers were made.

Introduction of works available on AHA's official website

Reference was made to AHA's official website for the proper classifications of manpower and collaborative construction. In terms of manpower, professionals, paraprofessionals, and non-professionals were differentiated, and the data were cross-compared with the aforementioned two types of reports. With regard to collaborative construction, the

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consultants participating in on-site construction were identified from the list and further analyzed for the elements of collaboration in construction.

Records of tool lending and returning

Information of the tools borrowed from the tool library for the six cases and how these tools were worn or damaged is summarized on Table 4.

TABLE 4. The research tools in six cases

Case Number	Hand-Used Tools		Power Tools	
	Used	Worn	Used	Worn
C1	36	2	22	2
C2	41	2	27	2
C3	85	1	28	3
NC1	36	0	24	0
NC2	64	0	33	0
NC3	49	0	33	0

RESULTS

Manpower

In the course cases, all of the participants were university students or postgraduates, belonging to the same age group, but coming from diverse backgrounds. In the non-course cases, the participants were relatively inconsistent in terms of age because they were composed of three age groups, namely, high school students, university students, and social personages (Figure 4).

FIGURE 4. Manpower analysis in six cases

Materials and Tools

In terms of tools, all of the six cases were mainly conducted using light power tools and some hand tools. The construction professionals participating in the course-based cases were agricultural workers, bamboo artists, and architects. Since some of these construction professionals did not achieve full participation due to their commitment to seasonal agricultural works, tool breakage was recorded. By contrast, in the non-course cases, the construction professionals were vocational-school teachers and local blacksmiths who performed supervision throughout the courses, so no tool breakage was recorded.

The materials used were mainly natural materials well known to the natives. Material supplements for the course-based cases were concentrated in the early stage, were mainly for consumables, and only contained a small amount of ironware. In the non-course cases, material supplements were concentrated in the later stage, and were mainly for ironware and lacquer. This indicates that there might have been excessive consumption during the early stage of the course-based cases and inaccurate estimations of material use during the early stage of the non-course cases.

Collaboration in Construction

Due to the engagement of local construction professionals and the use of materials familiar to the local people, in the event of worn or broken materials or tools, the local professionals could use their tacit knowledge to initiate the corrective actions, without needing to ask for external construction assistance from cities or wait for particular building materials.

A learning and work division mechanism was developed regardless of the backgrounds of different participants. According to this mechanism, every working item was assigned to a paraprofessional who took charge of the transference of experience and knowledge. The paraprofessional had learnt material processing and tool operation from competent professionals. To a processing panel composed of three or four non-professionals, the paraprofessionals provided guidance on how to form a co-learning production line for that particular working item. The paraprofessionals tried his/her best to answer questions from the non-professionals, and passed on the issues that he/she was unable to solve to the professionals, so as to unburden the on-site professionals and thereby allow the professionals to conduct overall management and quality control more effectively. With the paraprofessionals guiding the co-learning, the non-professionals in the panel could quickly learn about the working process and then master the related skills through repeated practice (Figure 5).

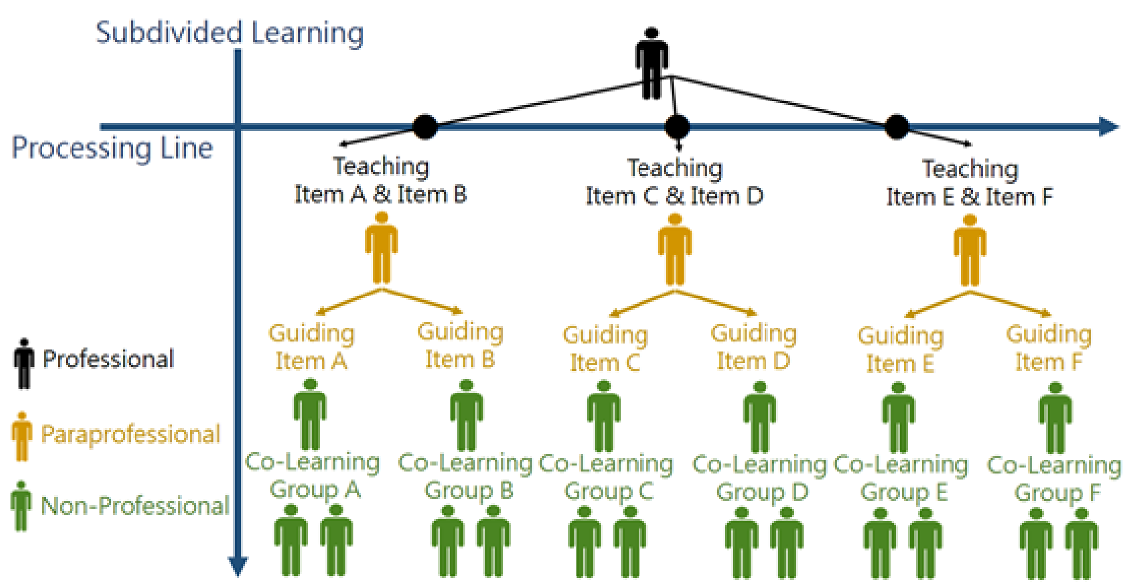

FIGURE 5. Subdivided learning and processing lines

Collaboration in Living

The use of such a mechanism meant that only the professionals were hired and paid with monetary compensation to provide technical instruction, while the paraprofessionals and non-professionals participated as volunteers or commensal workers. An interesting difference between the cases was that for the course-based cases, the professionals outside of the community received monetary compensation while the in-house professionals of the communities were engaged in the collaboration as commensal members. For the non-course cases, the in-house professionals of the communities received monetary compensation for their engagement, while the professionals outside of the community participated in the projects as volunteers. The information are shown in Table 5.

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TABLE 5. Collaborative Live in the six cases

Case Number	Professional	Paraprofessional	Non-Professional
C1	●☆	● △	● △
C2	●☆	● △	● △
C3	●☆	● △	● △
NC1	★△	▲ △	▲ △
NC2	✘△	✘ △	▲ △
NC2	★△	▲ △	▲ △

★/☆ Employment; ● Sharing Food; ▲/ △ Volunteer; ✘ No Participant Black are the Participants inside of the communityWhite are the Participants outside of the community

DISCUSSION

Participants with Different Backgrounds

Different from the design-build programs implemented in the Western world, the projects discussed in this study placed no limitations on the inclusion of the participants based on their backgrounds. Taking Auburn University's Rural Studio for example, the students can acquire practical experience in architecture through classroom courses. They are mainly juniors and seniors of the department of architecture, plus a small number of non-architecture. It is to allow the students to feel free to make mistakes in the school and thus accumulate tool experience and learn how to identify materials. When they are later sent to construction sites outside of the school, they are accompanied and guided by lecturers from the woodworking factories of universities, and master workers from general contractors who are all full of practical experience (Oppenheimer & Hursley, 2002). The cases referred to in this study also placed no limitations on the participants based on real-world working experience, and allowed the participants to contribute input from various perspectives and to create unexpected interpersonal interactions at the construction sites. There were social personages, university students, and high school students working and living together. In the event of on-site incidents, mature-age participants would actively play reassuring roles.

Knowledge Construction Throughout Collaborative Construction

The participants acquired the explicit knowledge required for construction works from the construction manuals. As to tacit knowledge, the professionals' knowledge was passed down to non-professionals through paraprofessionals by means of subdivided learning and processing lines. In addition, the processing flows of materials were broken down to working items. Skills in handling these working items were taught to paraprofessionals by professionals, and then the paraprofessionals teamed up with the non-professionals as co-learning panels. In such a panel, the paraprofessionals led the non-professionals to learn processing skills. Meanwhile, the professionals took full charge of quality control at the construction site and answered any constructional issues not solved by the paraprofessionals.

Construction Manuals Based on Collaborative Construction Model

The design team was required to provide the following information before the commencement of construction: working items, working procedures, and lists of materials and tools. Then, pre-fabrication was used to review the labor division, so as to develop a construction manual covering manpower, tools, materials, collaborative construction, and collaborative living as the norm for all participants. With such a common consensus, an efficient exchange of views and feedback about improvements among the participants and increasingly deepened collaboration were achieved.

Subdivided Learning and Processing Lines

The participation of vocational-school teachers and local professionals in this lines helped to compensate for the shortage of on-site professionals. Where there were enough professionals, these teachers and local professionals could help to significantly improve the working efficiency and provide the participants with instructions based on tacit knowledge. Another key part of this lines was the paraprofessionals who served to timely assist the smaller number of professionals by creating preliminary solutions for on-site problems, and acting as a reliable bridge between the non-professionals and the professionals for communication, thereby helping the professionals to impart their professional experience through subdivided teaching.

Good use of Local Tacit Knowledge and Proper Hybrid Construction

The practice wherein the local professionals transmitted tacit knowledge about local materials to the participants

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was beneficial for not only presenting the participants with a profound ecological vision and life vision, but also enhancing the confidence of the local professionals. This practice also helped the remote areas to avoid a reliance on urban construction systems. Moreover, by trying diverse materials, the participants could expand their experience of using different materials and explore the application of new materials. For example, hybrid construction, joining the force of digital makers, cooperative societies, and the woodworking factories of universities, provided the participants with additional architectural learning channels and knowledge sources, and inspired the participants to think further about the possible new forms of manpower-organizing strategies for future crowd-collaborative construction projects, thereby bringing about more possibilities to the ongoing maker movement and open source movement for crowd collaboration in architecture.

CONCLUSION

Changing the Way through which Participants Perform Collaborative Construction, Beginning with Design Sources

The design teams, materials, tools, and the selection of hybrid construction as the type of construction used have a direct impact on design, and can indirectly change the way through which on-site instructions are given. For example, if a designer is particularly familiar with a certain type of construction, the relevant materials and tools may be confirmed accordingly. More importantly, once hybrid construction is determined, the preliminary framework of the construction methods may be formed, and tectonic works are then continuously developed and deepened through this to-and-fro process, until a clear profile from design to construction is established. Feedback helps to guide the designer to maintain his/her original intention, and helps the construction team to provide efficient training, with the end goal of providing the participants with a complete set of constructional context.

Contributions and Follow-up Researches

This study contributes to the provision of a comprehensive reference for international organizations intending to conduct collaborative construction in Asia-Pacific. This study also provides suggestions about the strategies and mechanisms in accordance with the maker movement in terms of collaborative house building. This study is focused on the observations obtained at construction sites. It does not involve advanced design issues such as materials and tectonic works. These may be further explored in follow-up researches. In addition, the future application of digital tools in remote Asian-Pacific areas where power supply and industrialized systems are less available could also be a subject for further discussion.

LIMITATIONS AND RECOMMENDATIONS

In remote Asian-Pacific areas where industrialization is limited, a non-excessive reliance on urban construction systems is desired; thus, the principles for developing design and performing construction to this end are suggested:

A. Simplified construction methods adapted to regional needs: a. unitizable; b. tolerance-programmable; and c. maneuverable.

B. Tool consideration: a. low-risk, hand-held light power tools; b. easy processing using mainly cutting, drilling, and milling; and c. screw-based fastening.

C. Pre-fabrication: a. simulated troubleshooting for on-site situations; b. recognizing the challenges posed by gravity; and c. estimating the manpower and arranging the tools in terms of type and amount.

D. Hybrid construction: convening digital makers, gangs of workman, and general contractors for enriched interaction and learning among diverse professionals.

E. Construction manuals: establishing explicit knowledge on the basis of the open source model for collaborative construction. F. Subdivided learning and processing lines: establishing tacit knowledge with the help of local professionals and vocational-school teachers.

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