Tree Houses in Thailand: Lamphun Tree House Project at Films Farm School

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Abstract

In Thailand, housing development, with concrete as the primary building material, and intensive soil disruption, continues to grow. This often displaces natural systems and the eco services that those systems provide. Concrete also has a high carbon footprint and life cycle cost, and contributes toward the urban heat island effect by absorbing heat. Tree houses are a possible solution, where trees act as living posts to support a living space. The Lamphun Tree House Project featured Thai manufactured steel tree house attachment bolts (TAB's), originally designed in the USA, as connections between the living trees and a tree house frame. Empirical measurements were made on installed TAB's showing that a tree house using three *Tectona grandis* (Teak tree) was feasible. Such construction shows an answer toward solving some of the environmental and social problems associated with current standard construction in Thailand.

Keywords : Tree House, Workshop, Construction

1. Introduction

As human development and its associated problems of environmental degradation continue to grow, environmentally conscious humans are searching for means of living which minimize environmental burdens. [1] Tree houses that use tree trunks and their roots as the foundation of an elevated living space are a growing niche worldwide that fits into this category. [2] Trees adapt to applied mechanical forces by building more wood in areas of higher stresses. [3] This means the foundation of a tree house that uses living trees for support can get stronger over time. Recent advances in hardware and techniques have made building tree houses more practical. These advances have allowed for heavier, safer, longer life structures while allowing room for future tree growth. [2]

In Thailand, tree houses have many potential environmental and societal benefits over current standard house construction. Tree houses can take advantage of natural shading and transpirational cooling to significantly reduce the cooling load on a living space in Thailand's hot and humid climate. [4] Foundations of tree houses can be existing trees, roots, and soil instead of concrete. This reduces both the disruption of soils and fauna and effects of such on local ecology. With reduction or elimination of concrete use, tree houses can greatly reduce carbon footprints and life cycle costs over current standard house construction. [1] Most healthy living trees are termite resistant and in conjunction with metal connections between tree and house can allow for wooden or bamboo structures to be built reducing the risk of termite infestations. This provides a chance to reconnect building a house with traditional culture, where natural materials were the primary building materials and local environments were carefully observed.

Trees have many intangible benefits for humans, especially in urban environments. Trees have been shown to reduce the urban heat island effect, pollution and flooding. Trees produce oxygen, support biodiversity, improve quality of living and sense of well-being.(Hsieh et al., 2018) Thailand has over 3000 native tree species, many of which are in decline due to rapid urbanization and industrial farming. [5] A tree house or structure can showcase a visible human benefit which could help in preserving trees. A tree house depends on a healthy living tree for success. Building tree houses will likely result in expanded knowledge and techniques for maintaining health and longevity of trees despite the cohabitation of humans.

Films farm School is a learning center located in a rural area of Lamphun, northern Thailand, since 2015. Its founder, Saowanee Sangkara works on social impact stories, designing fictional and non-fictional digital content for Thai media. At the location itself there are many workshops and hands on activities. These include building dwellings and objects with natural building materials, garden design and cooking. Workshops focus on learning, creativity and sustainability, with a goal of maintaining a healthy lifestyle.

A treehouse workshop was held at Films Farm School from February 15-19th, 2019. The treehouse workshop involved; careful observation and biological study of living trees, tree house design, installing western style treehouse hardware in living trees, empirical strength analyses of the installed hardware, and carpentry. The workshop resulted in building and installing main beams and floor joists for a 16.5 m² tree house about three meters above the ground.

2. Building Process

2.1 Site and Tree Selection

The first step of the building process was to determine which trees on the property were suitable for building a treehouse and then pick a location. Trees under 30-cm diameter measured at 1.5-meter height were considered too small. Trees with a heavy lean, or of a short-lived species were not considered. The property featured 3 possible locations where healthy (no visible defects in trunk) tree(s) stood that warranted consideration. The first location featured two *Tectona grandis* (Teak) trees on a steep slope. [5] The second was an *Albiza saman* (Rain) tree also on a significant slope. [5] The third was a group of four *Tectona grandis* trees on a gentle slope. The group of 4 *Tectona grandis* were picked as a final location. This location was picked because it was within view from the other main buildings and considered a more publicly interactive site. Another advantage considered was it is easier to build a tree house with four trees than with one or two.

2.2 Function Planning

Once the location was finalized, tree house plans were drawn. The first step was to plan for the future function of the tree house. The tree house was to be a library and meeting space, and needed to be large enough for 10 people to comfortably sit and interact. After measuring a common area that is of similar use, a floor size of 3.5 meters by 4.75 meters was decided upon. Another requirement was keeping at least one tree trunk visible inside the tree house footprint to add to the allure of the space. Finally, all materials were to be of reclaimed local lumber to fit in with the surroundings of the property, and the mantra of Films Farm School.

2.3 Site Survey and Preparation

The site survey started by climbing all four trees at the site and remove any hazardous dead limbs to improve site safety. This involved climbing throughout the canopy and gave an opportunity to inspect the trees. Previous wounds on the trees showed good wound response (sealing without visible rot or insect damage). The views from different heights and locations while climbing provided reference to choose the desired height of the structure. A height of approximately 3 meters was chosen. This height afforded scenic views and aesthetically fit in with other buildings and terrain of the property. Scaffolding was set up over the entire footprint of the intended building zone to both protect the trees and make for a safe and efficient working zone.

A string was placed around the perimeter of the four *Tectona grandis* trunks connecting them with each other. The string was leveled using a 10-meter-long, 0.8-cm wide clear tube filled with water. The diameter of each tree was measured at the height of the string to make sure the trees would be big enough to install a treehouse attachment bolt (TAB). The trees were plotted on paper from a bird’s eye view perspective, with distances between them measured. The four trees were not oriented in a way to easily make a stable rectangular structure. The two trees upslope were more than 5 meters apart (longer than locally available wooden beams), and even if running a main beam between them were possible, the resulting parallel main beam between the other two trees would have been far closer than desired (<1 meter). The furthest tree was also leaning the most, so this tree was taken out of the plan altogether.

A new sketch was made with using just three trees to support the tree house, where one tree has a yoke. A yoke is a triangular beam fastened to the tree by two TAB's.(Nelson, 2014) The two main beams were to run off the top of the yoke to the other two remaining trees. A two-meter-long straight edge was centered and screwed to the yoke tree at a three-meter height to represent the top of the yoke, and a string was then strung from its outer edges connecting it to the other two trees to simulate the two main beams. The straight edge was adjusted until the angles of the beams matched each other for the purpose of symmetry. On the east side, the position of the bolts were then marked by placing a long screw at a right angle to where the string touched the trees. The trees were reexamined to make sure that position had a diameter large enough (>25cm), as trees are rarely round, but often asymmetrical.(Claus, 1998)

2.4 Supplies and parts

Final plans were sketched for the frame and a shopping list was made. 4 Tree house attachment bolts (TAB's) (Fig. 1), 5 associated brackets and 16 lag bolts were custom ordered from a metal shop. Various drill bits and screws were bought at building supply stores. Reclaimed lumber was purchased from a local supplier. The two main beams required four fairly uniform 5-meter-long pieces of lumber that passed a "bounce" test. This was performed by spanning the lumber 5 meters vertically positioned and lightly jumping on the middle. Movement was easy to detect in a 5-cm by 15-cm by 5-meter long piece of wood, but difficult for a person to detect in a 6cm by 20cm 5 meter long piece. Hence four 6-cm by 20-cm by 5-meter pieces were purchased. The top of the yoke also needed to be strong and uniform so another 6-cm by 20-cm by >5-meter beam was selected for purchase and was to be cut in half later. All purchased parts were cataloged and weighed.

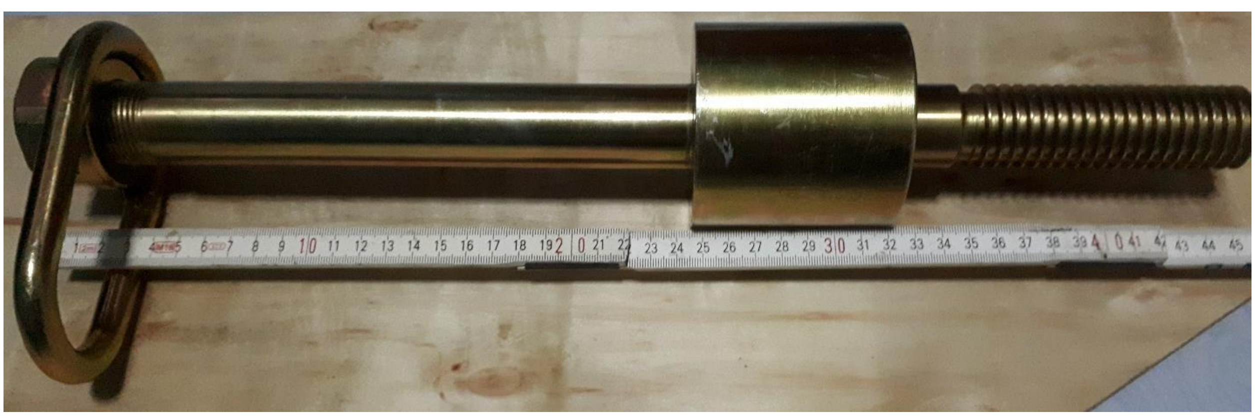

Fig. 1 Tree house attachment Bolt (TAB)

3. Construction

3.1 Installation of TAB's for dynamic side of beams

The first items installed in the building process were two TAB's on the two trees opposite of the tree that would receive the yoke. The screw marking the precise bolt position was moved up an inch at the same angle to provide a left to right drilling guide and the resulting hole marked the spot to drill. A 1-inch x 14-inch drill bit was used to drill a level guide hole for the three-stage drill bit that has the same profile as the TAB. The desired depth of the initial drilling was in this case 21-cm (length of thread, shank and boss of TAB) which was marked on the bit with a marker before drilling began. The hole was drilled level by putting a torpedo level on the 14-inch drill bit upon starting, and checking again several times during the drilling process. The drill bit was also pulled out of the tree several times to remove drilling shavings from the hole. In a living tree, the moist wood shavings expand rapidly upon heating as the drill bit turns in the wood and failure to take them out would have likely resulted in a bound drill bit. The hole was also cleaned by using a short piece of small rubber tubing to blow out the remaining saw dust. After 21-cm of depth was drilled, the drill bit was switched out for the three-stage bit. No further leveling was required as the guide hole was already level. Also, the first stage of the three-stage drill bit is a forstner bit, which removes most shavings upon drilling. The drill bit was still taken out several times to measure the depth of the hole for the boss. The hole was drilled to a depth of near three inches into the wood (measurement starts after the bark with a ruler). Once the drilling was completed, the last shavings were blown out with the small rubber tubing, and the hole was inspected with a flashlight. The inspection confirmed the wood inside the tree was clean and insect and rot free. The inside of the hole and the threads of the TAB were then oiled with Tung oil to resist future rot and to resist friction during installation.

The TAB was installed in the drilled hole by threading a nut on the end of the TAB and then turning it in with a ratchet wrench with a 47-mm socket. Level was checked every few turns with a torpedo level. If the TAB was level, full rotations of the ratchet were used. If the TAB was out of level upward or downward the ratchet was used in an up only or down only fashion until the TAB was level and full rotations of the ratchet resumed. An extension arm was put on the ratchet halfway through the installation to increase leverage and make it easier to turn in. Two strong people were needed simultaneously toward the end of the installation. The bolt suddenly stopped turning which signaled it was in all the way. The second TAB was installed in the second tree opposite of the yoke tree in the same fashion as the first.

3.2 Yoke top assembly

The top beam of the yoke was assembled before installing the first TAB on the yoke tree. It was assembled using two pieces of wood 5-cm by 18.5-cm by 2.5-m, with 1-cm thick spacers placed 40-cm apart at the fastener points. Every wood part was first measured, cut, sanded and oiled with Tung oil before assembly, for aesthetics, and for insect and water resistance. The spacers were included in the design to keep the beam "breathing" and provide stability against warping. Once the top of the beam was finished its height was measured, yielding 18.5-cm. The 10 meter tube water level was used off of the center of a TAB already installed on the dynamic side and a point 18.5-cm lower was marked on the center of the "yoke" tree. At this location a TAB was installed in a similar fashion to the others.

3.3 TAB testing

All 3 installed TABS were then tested to determine approximate strength. (Fig. 2) The first step was threading a hanger nut on the end of each TAB to enable hoisting a weight. Next, a dial gauge was set up on a point as close to the boss as conveniently possible. This was done by using a ratchet strap around the tree through a piece of a flat hollow steel post to act as a platform to hold the magnetic base of a dial gauge. The dial gauge was set to zero. A scale was used to weight the chain hoist (10 Kg) and two concrete benches (44 & 46 Kg). The chain hoist was attached to the hanger nut and the benches hoisted until they hung freely (100 Kg total). The deflection of the TAB was measured by reading the dial gauge. The weight was lowered and hoist was removed and the dial gauge was read again to attain permanent deflection (load bearing wood permanently compressed). The process was repeated with a further weight of 66 Kg added to make a total weight of 166 Kg. The same procedure was carried out on all three bolts.

An estimate was made of the installed TABs load capacity. This was done through calculations that included four assumptions. It was assumed that the arm and boss of the TAB had no elasticity, the fulcrum was at the end of the TAB shank, that the progression of deflection with additional weight would be linear, and that the acceptable tolerance of permanent deflection was .2mm. The result of the calculations was our average TAB theoretically could hold 5,359 Kg in an ideal "dead load" situation. To account for dynamic forces of wind and occupants of the future treehouse, as well as some error since the calculations were approximate and idealized, a 5 to 1 safety factor yielded a working load limit of 1,071.8 Kg per TAB. With four TABs in the treehouse the aggregate working load limit would then be 4287 Kg. This includes the weight of the structure, occupants, and contents.

(a) (b

Fig. 2 (a) TAB testing in Lamphun, (b) dial gauge setup.

3.4 Installing the yoke

The top part of the yoke beam was installed and leveled. It was held level by tightening the nut at the end of the TAB. Next, a straight edge was used as a right-angle guide to drill the fourth and final TAB about 170cm below the top of the yoke beam. This TAB did not get tested as it was too low to the ground to use the hoist to put weight on it. The legs of the yoke beam were assembled in the same style as the top of the yoke, but with lumber measuring 5cm x 15cm x 2 meters. On one end of each leg a bracket was fixed and on the other end a 30-degree angle was cut, with a second 2cm 90 degree cut off the resulting piece. The legs were independently slid onto the lower TAB and the future cuts were marked on the top of the yoke beam. The cuts were made on the top beam of the yoke and the legs were slid into place. The cuts were refined (sanding and additional sawing) until the joints sat tightly together. Two lag screws then were installed connecting each leg top to the top yoke beam, completing the yoke. (Fig. 3)

(a) (b)

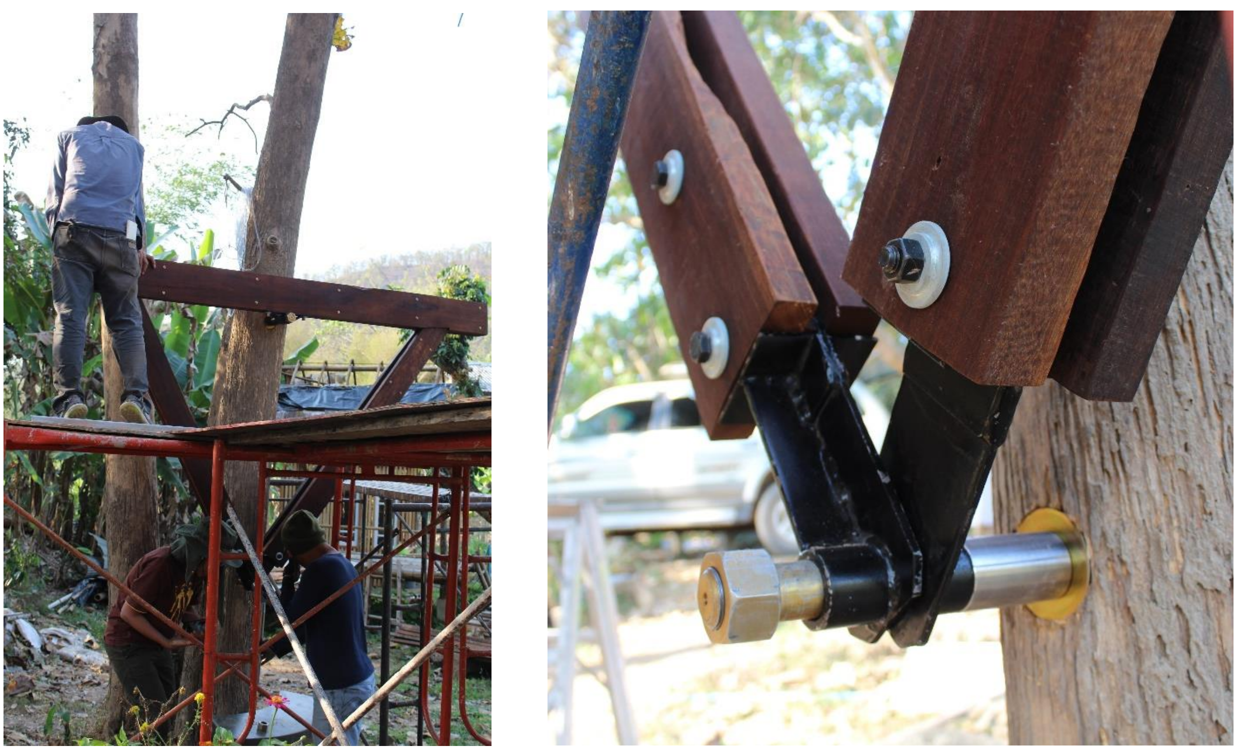

Fig. 3 (a) Completed yoke in Lamphun, Thailand, (b) Bottom of yoke.

3.5 Assembly and install of two main beams

The two large main beams (each two pieces of wood measuring 6cm x 20cm x 5 meters) were assembled with spacer blocks in the same fashion as the yoke top beam. Additionally, a 5cm x 5cm x 5-meter piece of wood was screwed onto the top side of each beam with the idea being that it would be an easy way to attach the future floor frame to the main beams. Next, the main beams were hoisted onto the yoke on one end and a TAB on the other with six people. Each person had a sling to make gripping easier, the beams weighed approximately 69 Kg each. Each main beam was slid until the cantilever over the yoke measured 70-cm. The point where the TABs touched the main beams was marked, and the sliding brackets were installed using that mark as a center point. Blocks and 5cmx5cm wood pieces were used to fix the beams position on the yoke side, yet allow for a slight amount of movement for high wind situations. On the non-yoke side, a wood piece was put across to fix the angle of the two beams in relation to each other, and keep them aligned during the installation of the floor frame.

3.6 Floor frame assembly and installation

The floor framing was made up of 4-cm x 7.5-cm lumber. The outside frame was made up of 4.5 meter lengths, with 32.5-cm blocking screwed against it to space the floor joists at 40-cm. The floor joists were 3.35 meters long and were cut identically using a chop saw with a stop at 3.35 meters. The middle five joists and outside frame and blocking were screwed together on the ground where working was easier. This arrangement allowed the assembly to be maneuvered around the trees and the beams. Over 10 people helped move the assembly into place as it was large and awkward to move. Once centered in place over the main beams the floor joists that fit well were screwed to main beam from underneath, via the small wood. The frame was checked for level with a straight edge. Floor joists that were too tall were adjusted by unscrewing and chiseling out where they touched the main beam. If they were too short washers were added as a spacer. Floor joists were added to complete the floor frame. (Fig. 3) Near the trees the spacing was adjusted to provide ample grown space (minimum of 20-cm) from any framing. Where this resulted in a space bigger than 40-cm, short joists and blocking were added as needed. The installed items weight was totaled at 455.3 Kg.

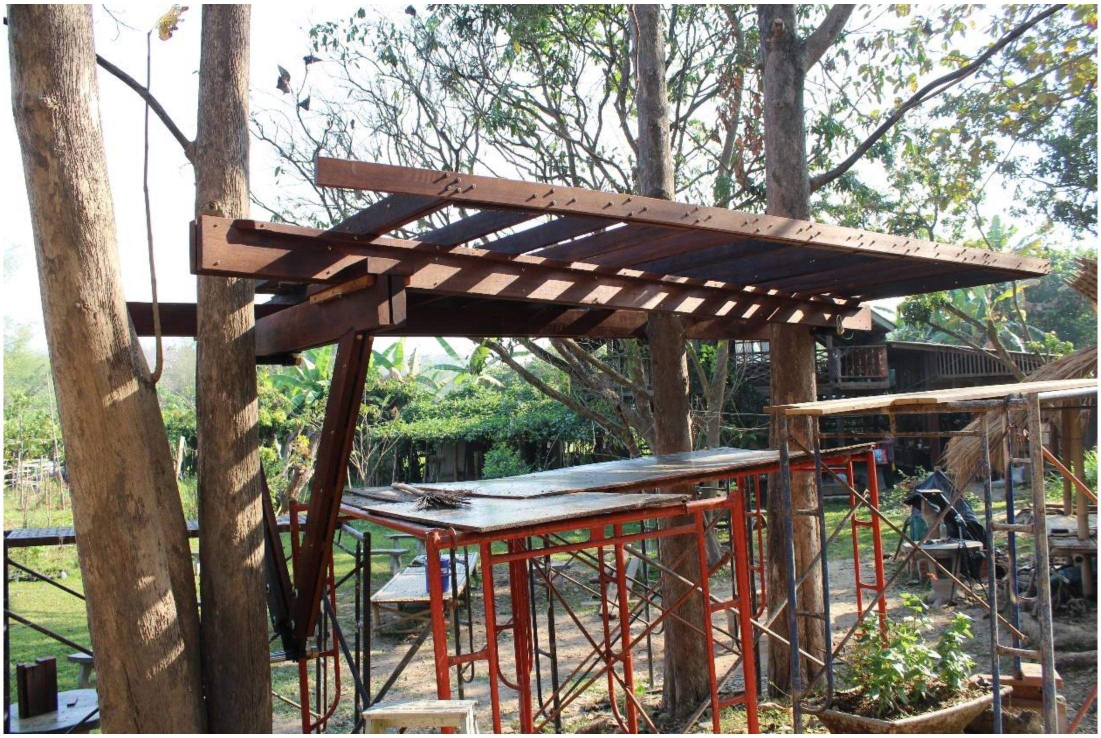

Fig. 4 Installed floor frame.

4. Conclusion and Discussion

The Lampoon tree house workshop revealed pre-requisites exist for successful tree house construction in Thailand. *Tectona grandis* (Teak) trees in this workshop were shown to be strong enough (through the TAB testing) and good candidates for such construction. Estimates were made that the four installed TAB's could safely hold 4287 Kg. The installed parts at the end of the 5 day workshop weighed 455.3 Kg, leaving room for an additional weight of 3,831.7 Kg for future construction, contents and occupants of the tree house.

Participants and visitors of the Lampoon Treehouse Workshop showed enthusiasm and a high level of interest in the project. Upon hearing the fact that the tree house was to be physically connected to the trees, participants showed visible excitement, wonder, and an eagerness to learn. The participants also showed great interest in being able to take part in constructing their own dwellings. The participants, even those with construction experience, exhibited little experience with screwing wood together, as nails are the standard fasteners for wood construction in Thailand. Treehouses built in the west primarily use screws as they are considered to resist loosening from the movements experienced in a treehouse setting.

There are challenges and limitations in Thailand for building treehouses. Many trees have high growth rates and grow all year which means more growth space must be allowed in general as compared to colder climates. Since it is so biodiverse, many trees have little written information about them adding to unknown problems. Also, the large range of elasticity and hardness between different species means that TAB's have to be made a bit bigger or smaller sometimes, despite the bore hole being the same size. High torque low speed drills required for drilling large holes in trees to install TAB's are not readily available, and would add a one-time cost of about 20,000 baht to a builder's toolkit to import a new one. Leaves can drop all year which makes it important to have a steep roof pitch to make them slide off, or provide easy access to maintain the roof. Insects are also abundant which makes screening and keeping them out difficult. Frequent lightning is also a concern in Thailand. Lightning protection is available for trees at risk, but is another unknown and considerable variable cost.

Building treehouses in Thailand also has advantages over building in cold climates. Since no heating is needed, it also leaves open the option to not have to insulate tree houses or seal tightly around trees, which makes for much easier construction compared to cold climates. Since there are no freezing temperatures, plumbing also doesn't require heating or insulation, making it simpler to build an actual living space.

With over 3000 species of trees, Thailand has many opportunities for tree houses. In theory, trees acting as living posts for tree houses could even be pre planted and arranged in a development. Such a plan would be unfeasible in a cold climate where trees grow so slowly. If successful, such a plan may be an opportunity have people and nature cohabitate.

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