

UNIT CONSTRUCTION METHOD

BACKGROUND OF THE INVENTION

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Field of the Invention

The present invention relates to a method of constructing a building, and in particular, relates to a unit construction method in which a building is constructed by connecting a plurality of rectangular hollow box-shaped units that are manufactured in
10 advance.

Description of the Related Art

In this type of unit construction method, a building is constructed by on-site assembly of the units manufactured in advance according to predetermined standards,
15 and it allows reductions in both the construction period and in costs in comparison to the convention construction method. Thus, the construction of buildings having a small-scale and simple structure such as detached houses has become more widespread than conventionally. In addition, recently there has been a trend to apply this type of unit construction method to comparatively large-scale buildings made of concrete.
20 Investigations are being carried out on constructing buildings such as condominium residences by fabricating in advance rectangular hollow box-shaped units made of concrete, and connecting them in plurality in both horizontal and vertical directions.

However, when the unit construction method described above is applied to buildings made of concrete, each of the surfaces of the units made of concrete must be
25 connected together in an air-tight state. However, this type of operation is not always

easy to carry out. In particular, in this type of unit construction method, the higher that the degree of completion of the units fabricated in advance is, the on-site work becomes reduced, and thus is advantageous. Therefore, during unit fabrication, incorporating even interior furnishings and carrying out the interior finishing work on the unit as well have been considered. However, in this case, in order to apply this type of unit construction method to buildings made of concrete, it is indispensable to develop an effective method of connecting the units together reliably and simply using only operations that are carried out outside of the unit because carrying out the operation of connecting the units together from inside the unit is difficult.

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SUMMARY OF THE INVENTION

In consideration of the above described problems, a first aspect of the invention is unit construction method comprising the steps of fabricating in advance rectangular hollow box-shaped units made of concrete and connecting these units in a vertical direction, a horizontal direction, or both directions, thereby constructing a building, comprising the steps of providing an engaging device for connecting the units together on the exterior surface of the units in advance; and connecting together and integrating units by using this engagement device by fastening the exterior surfaces of the units together tightly, and thus, the connection operation between the units can be carried only from the outside, and therefore has the superior effects that the degree of completeness of the units can be made sufficiently high and the thickness can be decreased because the rigidity is increased due to the integration of the engaging parts, and thus the unit can be made light weight.

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According to the second aspect of the present invention, the unit construction method according to the first aspect comprising the steps of forming a shearing cotter in

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advance to serve as an engaging device on the exterior surface on both sides of the units to be connected together and connecting together and integrating the units in a state that provides shearing strength in the in-plane direction by using said shear cotter and said hardening filler by compression attaching these units together using a hardening filler, and thus the units can be reliably and rigidly connected by an extremely easy and simple operation.

According to the third aspect of the present invention, the unit construction method according to the first or the second aspect comprising the steps of providing a connecting member to serve as an engaging device in a recess on the external surface of both units that are to be connected together; and overlapping both connecting members inside said recess and connecting together and integrating the units by engaging these connecting members using the hardening filler that fills the recess, and thus the units can be connected together reliably and rigidly by an extremely easy and simple operation.

According to the fourth aspect of the present invention, the unit construction method according to any of the first through third aspects comprising the steps of providing a recess and an anchoring member disposed inside this recess to serve as an engaging device on the external surface of one of the units that is to be connected; and disposing an anchoring member inside said recess on the other unit project, and connecting together and integrating the units by lapping both of the anchoring members inside said recess and fastening these anchoring members by a hardening filler that is filled into the recess, thereby connecting and integrating the units, and thus the units can be connected together reliably and rigidly by an extremely easy and simple operation.

According to the fifth aspect of the invention, the unit construction method according to any of the first through fourth aspects comprising the steps of: boring a splice sleeve into the external surface of one of the units to be connected as an engaging

device; and inserting the end of a reinforcing bar on the other unit into this splice sleeve project, and connecting together and integrating the units by inserting and engaging the end of this reinforcing bar in said splice sleeve, and thus the units can be connected together reliably and rigidly by an extremely easy and simple operation.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic drawing showing the first embodiment of the present invention.

Fig. 2A and Fig. 2B are enlarged drawings of the essential elements.

10 Fig. 3 is a drawing showing an example of another shear cotter of the same.

Fig. 4 is a drawing showing an example of another shear cotter of the same.

Fig. 5 is a drawing showing an example of another shear cotter of the same.

Fig. 6A and Fig. 6B are schematic drawings showing another embodiment of the present invention.

15 Fig. 7 is a schematic drawing showing another embodiment of the present invention.

Fig. 8 is a schematic drawing showing another embodiment of the present invention.

20 Fig. 9A and Fig. 9B are schematic drawings showing one example of the manufacturing method of the unit in the present invention.

Fig. 10A, Fig. 10B, and Fig. 10C are drawings showing the same in detail.

Figs. 11A and 11B are diagrams for integrating two panels by jointing ends of both panels.

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DETAILED DESCRIPTION OF THE INVENTION

An embodiment of the present invention will be explained while referring to Fig. 1, Fig. 2A, and Fig. 2B. Fig. 1 is a schematic drawing showing the situation in which a building is constructed by horizontally stacking and connecting the rectangular hollow box-shaped units 1 that are made of concrete, and Fig. 2A and Fig. 2B are enlarged drawings of the essential elements thereof. Unit 1 in the present embodiment comprises a floor slab 2, a ceiling slab 3, and wall slabs 4, each made of concrete. Furnishings have already been disposed therein, and finishing has been carried out.

In the present embodiment, the units 1 shown in Fig. 1 are sequentially stacked horizontally and connected, and as shown in Fig. 2A and Fig. 2B, the connections between these units 1 are carried out by compression attaching the ceiling slab 3 of the unit 1 on the bottom and the floor slab 2 of the unit on the top using mortar 5, and thereby integrally engaging the ceiling slab 3 and the floor slab 2. Shearing strength is provided to these engaging surfaces in the in-plane direction by forming in advance shear cotters 6 as engaging devices at necessary locations on the exterior surface of the ceiling slab 3 and the floor slab 2.

Specifically, as shown in Fig. 1, Fig. 2A, and Fig. 2B, relative projections 8 are formed between these recesses 7 by these recesses 7 being formed at equal intervals on the outer periphery of the ceiling slab 3 and the outer periphery of the floor slab 2 of the units 1, and the shear cotter 6 is formed by these recesses 7 and projections 8. In the case of the example shown in the figures, the positions and shapes of the shear cotters 6 on both sides are set such that the recesses 7 of the ceiling slab 3 oppose the projections 8 of the floor slab 2, and at the same time, the projections 8 of the ceiling slab 3 oppose the recesses 7 of the floor slab 2. Moreover, if these shear cotters 6 can exhibit effective resistance in the direction in which the shear force acts, the shape can also be pointed, linear, or a grid shape. In addition, these shutter cotters 6 can be provided

across the entire surface of the ceiling slab 3 and the floor slab 2, but as shown in the figure, providing them at the peripheral part where the shear stress is most intense is usually sufficient.

As shown in Fig. 2A, in the operation of connecting above-described the units 1
5 together, mortar 5 is spread at a predetermined thickness over the entire surface of the ceiling slab 3 of the bottom unit 1, and thereupon, the top unit 1 is suspended and lowered. Thereby, as shown in Fig. 2B, the mortar 5 is trapped in the recesses 7 due to the dead weight of the top units 1, and in this state, the ceiling slab 3 and the floor slab 2 are integrally engaged by the mortar 5 in a state of compression attachment due to the
10 mortar 5 hardening, and thereby, the upper and lower units 1 are mechanically connected together. Furthermore, the shearing strength in the in-plane direction (the horizontal direction) of the engaging surfaces is sufficiently guaranteed by between the upper and lower shear cotters 6 and the mortar 5 that is interposed therebetween.

In this manner, according to the unit construction method of the present
15 invention, with only an extremely simple and easy operation, the units 1 can be reliably and rigidly connected together, and furthermore, it is possible to carry out this operation completely from the outside of the units 1, and any operations inside the unit 1 are completely unnecessary. Thus, it is possible to sufficiently increase the degree of completeness of the unit 1, and thus this type of unit construction method can be
20 effectively applied to a large-scale building made of concrete.

Furthermore, in the above-described case, the ceiling slab 3 and the floor slab 2 can be regarded as one slab because they are structurally integrated by the shear cotters 6 and the mortar 5, and therefore, the ceiling slab 3 and the floor slab 2 can be made thin, and as a result, the dead weight of the units 1 can be decreased. This means that in the
25 conventional technology, the ceiling slab 3 and the floor slab 2 are not considered to be

actively integrated when they are stacked in an air-tight state, and thus the ceiling slab 3 and the floor slab 2 behave structurally independently, and therefore their respectively required thickness must be optimally set independently. However, in the present embodiment, when the ceiling slab 3 and the floor slab 2 are stacked and integrally engaged, they behave as a unit and thereby the rigidity is increased. Thus, the respective thickness can be decreased by an amount equivalent to that increase in rigidity.

Concretely, the rigidity of a slab having a Young's coefficient E , width b , and thickness h is represented by:

$$E \cdot I = E \cdot b h^3 / 12,$$

and the rigidity in the case that two slabs are stacked is represented by:

$$2 E \cdot I = E \cdot b h^3 / 6.$$

Thus, when their rigidities are equal, the rigidity of one slab having a thickness h_1 and the rigidity of two slabs having a thickness h_2 are represented by:

$$E \cdot b h_1^3 / 12 = E \cdot b h_2^3 / 6,$$

and

$$h_1^3 = 2 h_2^3, \text{ thus}$$

$$h_1 \approx 1.26 h_2 \text{ (} h_2 \approx 0.79 h_1 \text{)}.$$

A concrete numerical example is provided as shown below. Since the rigidity obtained by stacking two slabs, each having $h_2 = 100$ mm (that is, total thickness is $2h_2 = 200$ mm) is equal to the rigidity of one slab having $h_1 = 141$ mm, the thickness of the conventional structure employing the ceiling slab 3 having a thickness of 100 mm and the floor slab 2 having the thickness of 100mm can be reduced to 141 mm when they are integrated, which suggests that each thickness of the ceiling slab 3 and the flooring slab can be reduced to 70.5 mm). Accordingly, the total thickness can be reduced by 59 mm. Thus, the total weight of the unit 1 is reduced and the cost of the unit is also reduced and it is thereby possible to obtain an extremely reasonable structural which is able to improve the operating efficiency. Moreover, it is possible to completely integrate two slabs as being $h_2 = 0.5 h_1$, if integration is possible. In the case that the finally required slab thickness h_1 is, for example, 100 mm, it is possible to obtain a slab having a thickness of 100 mm and having a rigidity equal to that of a slab having a thickness of 100 mm, by integrating two slabs each having a thickness of 50 mm.

An embodiment of the present invention has been explained above, but this embodiment is only one example and the present invention is not limited by the above embodiment. It is possible to modify the above embodiment for various applications and to change the structure for various structural designs. For example, the shear cotteners 6 shown in shown in Fig. 3 to Fig. 5 can also be used advantageously. The shear cotter 6 shown in Fig. 3 forms relative recesses 7 between the projections 8 by forming projections 8 on the ceiling slab 3 of the unit 1 (that is, in the parts other than the shear cotter 6, the thickness of the ceiling slab 3 is thicker than that shown in Fig. 2) and the projections 8 and recesses 7 of the ceiling 3 and the floor 2 respectively oppose each other. In the shear cotter 6 shown in Fig. 4, the platform-shaped projections 7 are formed on both the ceiling slab 3 and the floor slab 2. In the shear cotter 6 shown in

Fig. 5, recesses 7 that have similar semi-circular shapes are formed. All of these embodiments described attain the same effects. Of course, irrespective of the shape of the shear cotters 6, the position and range can be suitably set depending on the anticipated shear stress.

5 In addition, in the embodiment described above, a mortar 5 is used as hardening filler that is interposed between the units 1 to attach them by compression, but the units 1 can be integrally engaged together by filling the space between the units without a gap remaining and allowing the mortar 5 to harden naturally. If sufficient shear strength can be provided, the invention is not limited to the mortar 5, and for example, various types
10 of adhesives, resins, or the like can be used.

One of preferable examples to be used in place of the mortar 5 is CRC 30 (Compact Reinforced Composite) or CRC-like high performance composites. CRC 30 is an ultra-high strength fiber reinforced composite made of special high grade cement, aggregate, admixture (AE water reducing agent, high performance water reducing agent,
15 and high performance AE water reducing agent), and fibers which include ultra high strength steel fiber or other fibers. In general, CRC 30 has a water cementitious material ratio is less than 20%, and has a compression strength of over 100N/mm². The joint strength of CRC 30 is around 55 N/mm², when the compression strength is 130 N/mm².

20 Furthermore, above only an explanation of the case in which the units 1 are connected when stacked in a horizontal direction has been explained, but in the case that the units 1 are connected in a vertical direction, of course the side wall slabs 4 that form the units 1 can be similarly connected together and integrated. In addition, in the case that there are members corresponding to pillars and beams in the units 1 and these
25 members must be connected together, these members can be connected together and

integrated in a similar manner.

Above, an embodiment and modifications thereof have been explained, and below other embodiments will be described.

Fig. 6A and Fig. 6B show an example of a three-dimensional structure by
engaging iron reinforcing bars 11 as connecting members in the recess 10 as an engaging
device for connecting units 1 in both the horizontal and vertical directions. Specifically,
as shown in Fig. 6B, in the engaging device in the present embodiment, a recess 10 is
formed on the outer surface of the peripheral edge of the ceilings 3 of both of the units 1,
and at the same time, reinforcing bars 11 are provided so as to project from each of the
recesses 10 into the other unit 1 side, and the distal end thereof is disposed inside the
recess 10 of the other unit 1. Both of the reinforcing bars 11 overlap in the recess 10,
and they are engaged in the form of a lap joint by the mortar 5 that fills the recess 10.
Thereby, both of the units 1 are connected and integrated.

When the aforementioned CRC 30 is applied to the unit 1 in the connecting
structure shown in Fig. 6B in place of the mortar, the following advantageous effects are
confirmed.

(1) Since the ceiling and the floor of the three-dimensional module 1 are formed by
slabs having a thickness of 100 to 120 mm, it is desirable to form the connecting recess
as small as possible. When CRC 30 is used, one side of the recess can be an
appropriate dimension of about 10 cm because a necessary structural strength can be
obtained when a reinforcing bar with a diameter of d is covered by a CRC 30 cladding
having a size of ten times ($10d$) of the diameter of the reinforcing bar.

(2) It is desirable to produce the three dimensional module within a short term. Since
the CRC 30 material can be solidified within half a day, the three dimensional module
can be constructed within a day.

- (3) It is difficult to fill, for example, a mortar 5 in the recess, because many reinforcing bars are crowded in the recess. However, it becomes easy to fill the recess when CRC 30 is used, because it is possible to arrange the reinforcing bars in one plane without crossing each other or bending, and it even becomes possible to fill while the reinforcing bars on both recesses are separated.
- (4) Since the CRC 30 mortar 5 has a high fluidity when filling the recess, it is possible to fill CRC 30 even into a shallow and narrow recess without forming void; and therefore, even an unskilled operator is able to carry out the filling operation.
- (5) Since the CRC 30 mortar 5 is viscous and the water content thereof is low, it is possible to apply the CRC 30 material to the jointing region of the three dimensional module without forming through holes (no-leakage) even when applied to the finished surface.
- (6) Since a three-dimensional module can be integrated within a short period by use of the CRC 30 material, it is possible to demolish and dismantle the temporary materials used for securing the accuracy of the module without delay.

In Fig. 7, in the case that the units 1 are similarly connected horizontally and vertically, a recess 10 is provided in the outer surface of one of the units 1 (the bottom unit in the figure) and an anchoring member 12 is provided in the recess 10 thereof as an engaging device for engaging the units 1 together horizontally. In the other unit 1 (the top in the same figure) an identical anchoring member 12 disposed in this recess 10 projects, and in the recess 10 both the anchoring members 12 are horizontally lapped, they are engaged in the form of a lap joint by the mortar 5 that fills the recess 10, and thereby the units 1 are connected together and integrated. In this case, an anchoring head part that is integrally formed on the distal end of the reinforcing bar can be suitably used as an anchoring member 12.

The above-described integration of modules shown in Fig. 7 can be carried out by use of CRC 30 in place of mortar. When CRC 30 is used, the preferable effects are obtained as described below.

- (1) Since the ceiling and the floor of the three-dimensional module 1 are formed by slabs having a thickness of 100 to 120 mm, it is desirable to form the connecting recess as small as possible. When CRC 30 is used, one side of the recess can be an appropriate dimension of about 10 cm because a necessary structural strength can be obtained when a reinforcing bar with a diameter of d is covered by a CRC 30 cladding having a size of ten times ($10d$) of the diameter of the reinforcing bar.
- (2) It is desirable to produce the three dimensional module within a short term. Since the CRC 30 material can be solidified within half a day, the three dimensional module can be constructed within a day.
- (3) It is difficult to fill, for example, a mortar in the recess, because many reinforcing bars are crowded in the recess. However, it becomes easy to fill the recess when CRC 30 is used, because it is possible to arrange the reinforcing bars in one plane without crossing each other or bending, and it even becomes possible to fill while the reinforcing bars on both recesses are separated.
- (4) Since the CRC 30 mortar has a high fluidity when filling the recess, it is possible to fill CRC 30 even into a shallow and narrow recess without forming void; and therefore, even an unskilled operator is able to carry out the filling operation.

In Fig. 8, a splice sleeve 13 is bored into the outer surface of one of the units 1 (the upper one), and at the same time, the distal ends of the reinforcing bar 14 that are inserted into this splice sleeve 13, and thereby both of reinforcing bars 14 are engaged by the splice sleeve 13 project, the distal end of the reinforcing bar 14 is inserted into and engaged with the splice sleeve 13, and both of the units 1 are connected together and

integrated. In order to engage the reinforcing bar 14 to the splice sleeve 13, either the reinforcing bar 14 can be inserted first and then a hardening filler such as a mortar 5 filled into the splice sleeve 13, or when the reinforcing bar 14 is inserted into the splice sleeve 13, their mechanical connections can be automatically performed with ease.

5 Figs. 11A and 11B shows a structure for integrating two panels by jointing ends of both panels by engaging anchor reinforcing bars 11 of each panel 2 or 4 and by filling the corner with CRC 30. The integration of panels 2 and 4 by CRC 30 is advantageous and the following effects are observed.

(1) Since the ceiling and the floor of the three-dimensional module 1 are formed by
10 slabs having a thickness of 100 to 120 mm, it is desirable to form the connecting recess as small as possible. When CRC 30 is used, one side of the recess can be an appropriate dimension of about 10 cm because a necessary structural strength can be obtained when a reinforcing bar with a diameter of d is covered by a CRC 30 cladding having a size of ten times ($10d$) of the diameter of the reinforcing bar.

15 (2) It is desirable to produce the three dimensional module within a short term. Since the CRC 30 material can be solidified within half a day, the three dimensional module can be constructed within a day.

(3) It is difficult to fill, for example, a mortar 5 in the recess, because many reinforcing bars are crowded in the recess. However, it becomes easy to fill the recess when CRC
20 30 is used, because it is possible to arrange the reinforcing bars in one plane without crossing each other or bending, and it even becomes possible to fill while the reinforcing bars on both recesses are separated.

(4) Since the CRC 30 mortar 5 has a high fluidity when filling the recess, it is possible to fill CRC 30 even into a shallow and narrow recess without forming void; and therefore,
25 even an unskilled operator is able to carry out the filling operation.

(5) Since the CRC 30 mortar is viscous and the water content thereof is low, it is possible to apply the CRC 30 material to the jointing region of the three dimensional module without forming through holes (no-leakage) even when applied to the finished surface.

5 (6) Since a three-dimensional module can be integrated within a short period by use of the CRC 30 material, it is possible to demolish and dismantle the temporary materials used for securing the accuracy of the module without delay.

(7) When the CRC 30 having a strength of 10d is used, it is necessary to use only a small number and linear (not bent) anchor steel bars. Accordingly, the connecting recess can
10 be filled by CRC 30 easily.

In each of the embodiments described above, similar to the first embodiment, the units 1 can be reliably and rigidly connected together only by operations carried out outside the units 1, and since each of the units 1 is integrated in an air-tight state, the thickness of each of the units can be made 50 to 70% thinner than conventionally, and
15 thus the units 1 can be made light weight.

Moreover, the embodiment showed in Fig. 6 can also be applied to the case in which the units 1 are connected horizontally, and the embodiments shown in Fig. 7 and Fig. 8 can also be applied to the case in which the units 1 are connected in a vertical direction. In addition, the embodiments shown in Fig. 6 to Fig. 8 can be arbitrarily
20 combined with the first embodiments shown in Fig. 1 to Fig. 5, and the units 1 can be connected in both the horizontal and vertical directions.

We note that the units 1 used in the each of the embodiments described above can be manufactured by suitable methods, and one of these advantageous manufacturing methods is shown in Fig. 9 to Fig. 10. As shown in Fig. 9A, the floor mold 20 for the
25 floor slab formation and the wall mold 21 for the wall surface slab formation can be

assembled by being supported by the temporary support frame 22 and platforms 23, concrete poured into these frame molds, and thereby, as shown in Fig. 9B, the precast concrete box body 1A comprising the floor slab 2 and the wall slabs 4 is formed in an inverted state. At the same time, as shown in Fig. 10A, the ceiling slab 3 is formed separately as a flat precast concrete slab 1B, and the box body 1A and precast concrete slab 1B that serves as the ceiling slab 3 are assembled and integrated, and thereby the unit 1 is completed. In this case, the integration of the box body 1A and the precast concrete slab 1B can be carried out similarly to the structure in which the units shown in Fig. 6B are connected together. That is, as shown in Fig. 10B, recesses 10 are formed on the upper end of the wall surface slabs 4 and the peripheral edge of the ceiling slab 3, and as shown in Fig. 10C, after engaging the edges of the ceiling 3 into the recesses 10 of the wall surface slabs 4, both of the reinforcing bars 11 are bent and overlapped in the recess 10 of the ceiling 3, the recesses 10 are filled with a mortar 5, and thereby both reinforcing bars 11 are engaged in the state of a lap joint. Thus, the wall surface slabs 4 and the ceiling slab 3 are integrally connected, and the unit 1 is completed.

What is claimed is:

1. A unit construction method comprising the steps of fabricating in advance rectangular hollow box-shaped units made of concrete and connecting these units in a vertical direction, a horizontal direction, or both directions, thereby constructing a building, comprising the steps of:

providing an engaging device for connecting the units together on the exterior surface of the units in advance;

connecting together and integrating units by using said engagement device through a close attachment of exterior surfaces of said units to each other;

forming a shearing cotter in advance to serve as an engaging device on the exterior surface on both sides of the units to be connected together; and

connecting and integrating said units by compression attaching said shearing cotters together through solidification of said hardening filler into a state that provides shearing strength in the in-plane direction by use of said shear cotters and said hardening filler.

2. A unit construction method according to claim 1 comprising the steps of:

providing a connecting member to serve as an engaging device in a recess on the external surface of both units that are to be connected together; and

overlapping both connecting members inside said recess and connecting together and integrating the units by fixing these connecting members using said hardening filler that fills the recess.

3. A unit construction method according to claim 1 comprising the steps of:
providing a recess as a connecting member in an external surface of one of the units which are to be connected and an anchoring member disposed inside said recess to serve as an engaging device;
disposing an anchoring member in a recess of another unit protruding from said unit; and
connecting together and integrating said both units by lapping both of the anchoring members inside or said recess and fastening these anchoring members using said hardening filler that fills said recess.
4. A unit construction method according to claim 1 comprising the steps of:
embedding a splice sleeve as an connecting device in the external surface of one of the units to be connected;
protruding one end of a reinforcing bar from the external surface of the other unit to be connected; and
inserting the end of a reinforcing bar of the other unit into said splice, sleeve of one unit for integrating both units.
5. A unit construction method according to claim 2 comprising the steps of:
embedding a splice sleeve as an connecting device in the external surface of one of the units to be connected;
protruding one end of a reinforcing bar from the external surface of the other unit to be connected; and
inserting the end of a reinforcing bar of the other unit into said splice sleeve of one unit for integrating both units.