Countermeasures against tsunami in Kii-Tanabe station reconstruction project

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Abstract

1. Intoroduction

Kii-Tanabe Station is located in Tanabe-shi (the southern part of Wakayama Prefecture) and it is the nearest station to the World Heritage Site " Sacred Sites and Pilgrimage Routes in the Kii Mountain Range ". The station building is located about 1 (km) from the coast (Fig.1) and it is included in the tidal wave flooding of the Nankai Trough earthquake. The tsunami of about 2.9 (m) high (reference water level) is expected to hit 16minutes after the earthquake.

In the event of a major earthquake, which is expected to result in a tsunami, it is assumed that the area will be evacuated to the surrounding hills where the tsunami will not reach. However, if there is a person who can't escape by any event, it is necessary to ensure the safety of the people (passengers, station staff, neighbors, etc.). Therefore, a part of the station building was planned to have the function as a temporary evacuation facility (tsunami evacuation building).

2. Structural performance as the tsunami evacuation building

(1) Earthquake resistance: Minor damage and continued use: Importance factor1.25
(2) Anti-tsunami: The tsunami's wave power prevents it from collapsing, falling, or lifting.

The one-story part (Concourse Area) and the three-story part (Office Area) were structurally separated by expansion joints. The three-story part was planned as the tsunami evacuation building. The meeting room and the roof of the third floor were temporarily evacuated. An outdoor staircase that can go directly from the ground to the roof was provided, and it was planned to facilitate evacuation from the platform by connecting the outdoor stairs and the station overpass. In addition, electrical equipment and mechanical equipment were installed on the second floor and the roof higher than the standard water level, and considered early recovery after the tsunami. (Fig. 2)

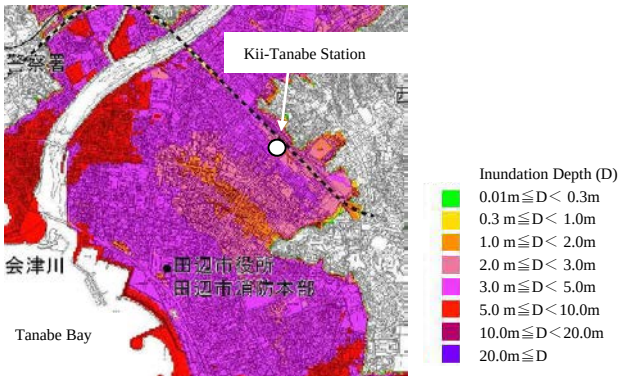

Fig.1 Nankai-trough disastrous earthquake tidal wave flooding assumption figure (Tanabe-shi) (Wakayama Pref.)

Table 1 Building Data

Location	1-24 Minato, Tanabe-shi, Wakayama Prefecture
Principal use	Station building
Building area	693.96 ㎡
Total floor area	926.06 ㎡
Structure	Steel frame (Cast-in-place concrete pile)
Number of stories	+3
Completion	2019.8

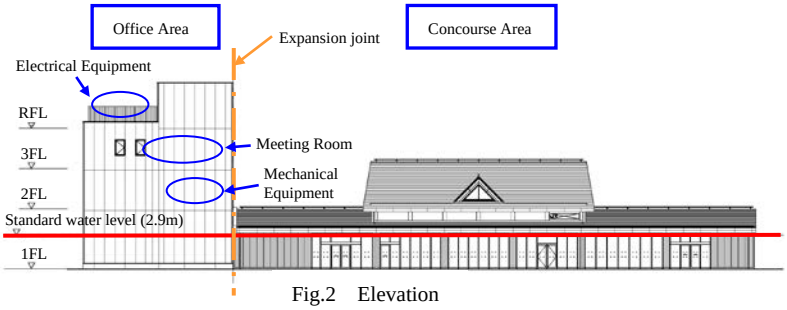

Fig.2 Elevation

Keywords: Nankai Trough Earthquake, Tsunami Evacuation Building, Station

1. Overview

Kii-Tanabe Station is the station of West Japan Railway Company (hereinafter referred to as " JR-West ") located in Tanabe City located in the southern part of Wakayama Prefecture. It is the closest station to the World Heritage Site "Sacred Sites and Pilgrimage Routes in the Kii Mountains" and is one of the most important stations of JR-WEST in the southern part of Wakayama Prefecture. The station building is located about 1km from the coast. (Fig. 1) It is included in the tsunami inundation area of the Nankai-trough disastrous earthquake established by Wakayama Prefecture. A tsunami of about 2.9m high (reference water level) is expected to hit 16 minutes after the earthquake. Therefore, when the station building was renovated, a part of the station building was planned to function as a temporary evacuation facility (tsunami evacuation building). In this report, we report on the contents of the plan.

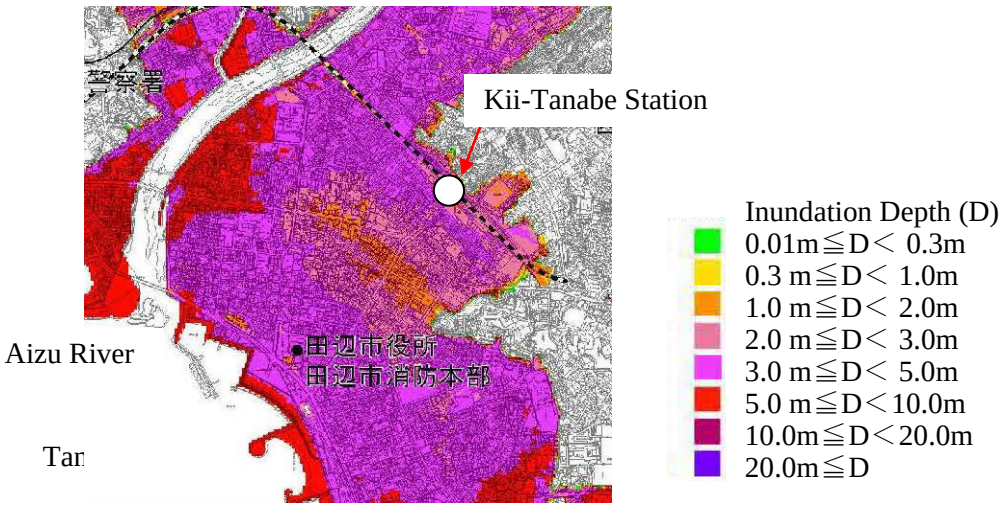

Fig.1 Nankai-trough disastrous earthquake tidal wave inundation assumption figure (Tanabe-shi) (Wakayama Pref.) [1]

2. Tsunami Evacuation Building

The safety level of the evacuation site was determined in the tsunami evacuation measures in Wakayama Prefecture.[2] If there is a possibility of the tsunami coming, it is a principle to evacuate to evacuation sites outside the tsunami inundation area (level 2) or evacuation sites in areas where there is no risk of inundation. (level 3) However, when there is no time to evacuate to the emergency evacuation site (Level 2, 3), it is the tsunami evacuation building that the site is designated as an emergency evacuation place (Level 1). Tsunami evacuation buildings are constructed as facilities (limited to artificial structures) for local residents to carry out temporary evacuation and evacuation actions in areas expected to be flooded by the tsunami.

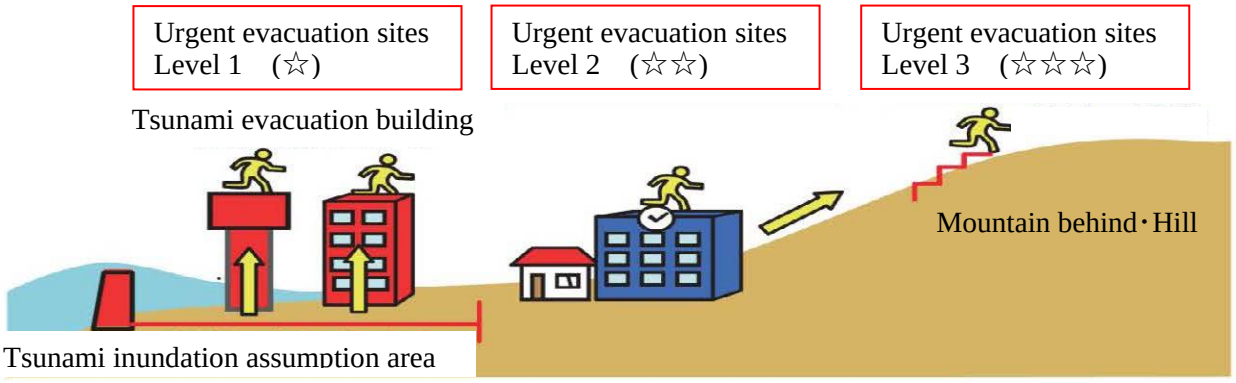

Fig.2 The safety level of the evacuation site [3]

3. Reconstruction plan

3.1 Usage of Kii-Tanabe Station

Kii-Tanabe Station is located in the central part of Tanabe City. It is the station used by students and working people. And, It is also the closest station to the World Heritage Site of the Kii Mountains, "Sacred Sites and Pilgrimage Routes in the Kii Mountains," and it is used by many tourists. On the other hand, it is the base station of JR-West in the southern part of Wakayama Prefecture, and it is required that the station acts as the disaster prevention base station at the time of emergency

Therefore, it was planned as the station with the service facility for passengers such as waiting rooms and stores (convenience store), and the station office (passenger response and disaster prevention base). It is shown the specifications of the planned building in Table 1, each floor plan in Fig. 3, shows the appearance photograph after completion in Fig. 4.

Table 1 Building data

Location	1-24 Minato, Tanabe-shi,Wakayama Prefecture
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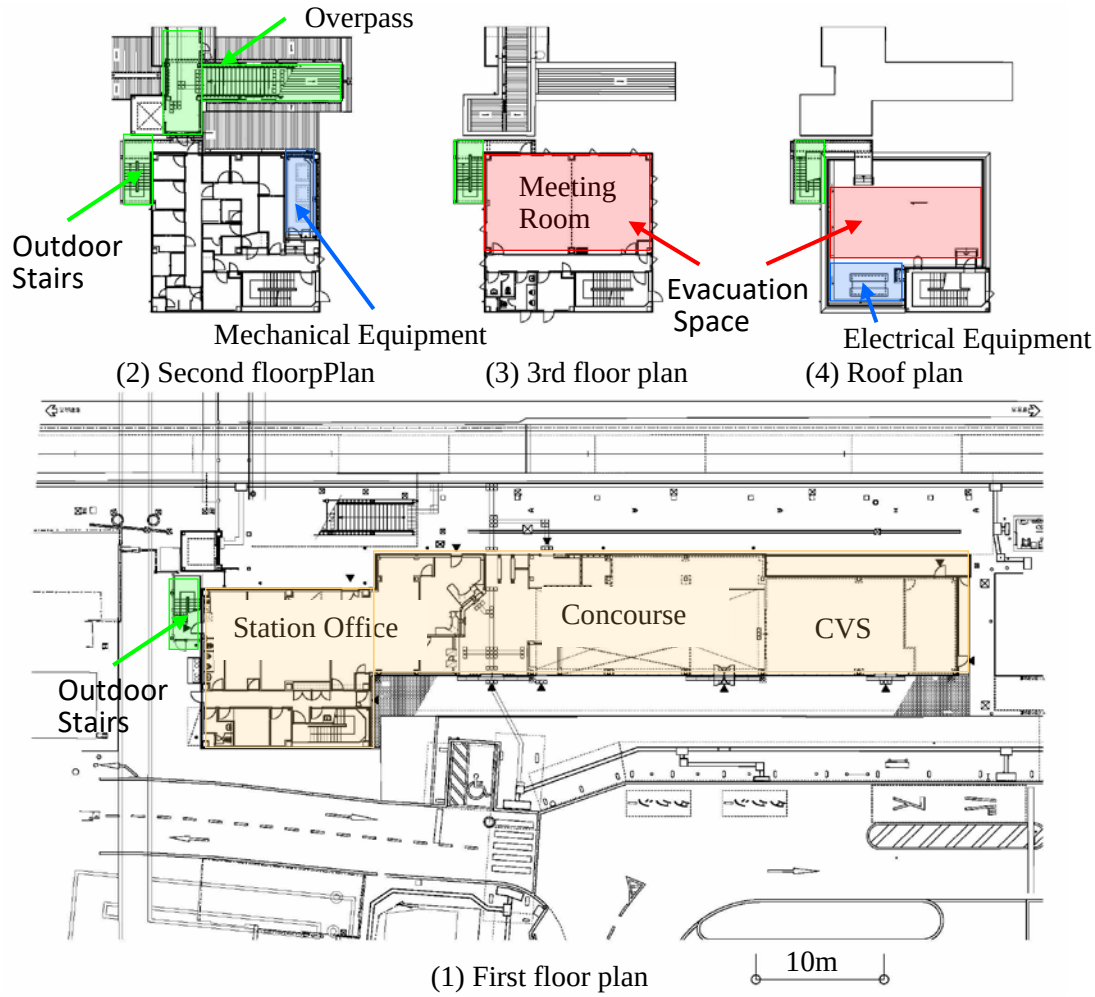

Fig.3 Plan

Fig.4 Photograph of exterior

3.2 Planning as a Tsunami Evacuation Building

In the event of the disastrous earthquake where the tsunami is assumed, it is assumed that the tsunami evacuates to the surrounding hilly areas that do not reach. However, if there is persons who are late to escape by any chance, it is necessary to ensure the safety of those people (passengers, station attendants, surrounding residents, etc.). Therefore, we planned to have a part of the station building (office part) as a tsunami evacuation building which is an emergency evacuation site (level 1). The reference water level for tsunamis caused by the Nankai Trough earthquake at Kii-Tanabe Station is about 2.9 m. As an evacuation space,the third floor meeting room(1FL + 8.7m)and the roof (1FL+12.2m). The height of the reference water level is as shown in Fig. 5.

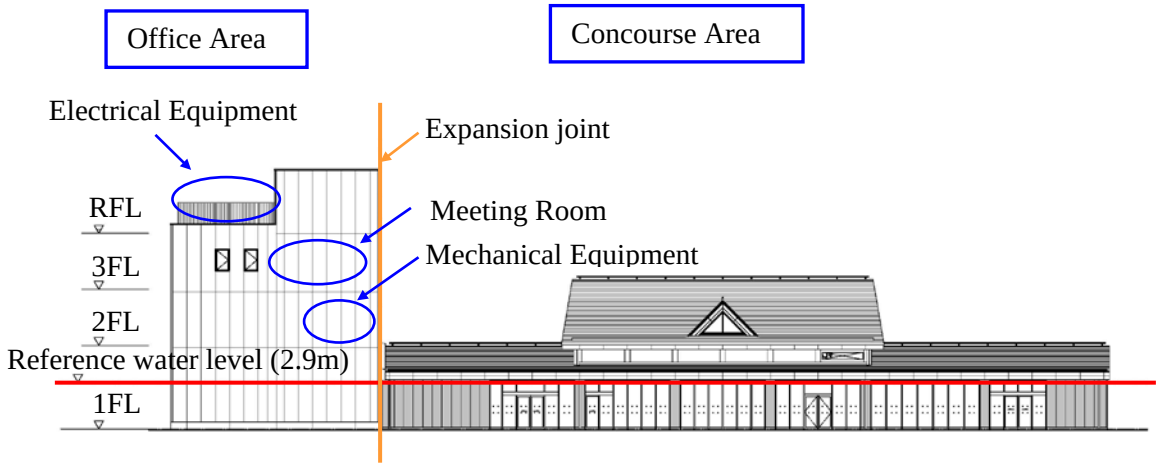

Fig.5 Elevation

＊Reference water level: It shows the height (water depth) from the toposurface, taking into account the rise when the tsunami collides with a building or the like.

After the disastrous earthquake, it is as follows that the emergency evacuation plan in the case where evacuation to the surrounding hilly areas that tsunami is assumed not to reach is not in time.

The station attendants use the stairs in the office to evacuate to the evacuation space. On the other hand, residents and tourists in the vicinity use the outdoor stairs of the office part to evacuate to the evacuation space. Passengers at the platform go to the outdoor stairs of the office part from the second floor of this overpass. The entrance to the outdoor stairs is locked in normal times, but in the event of the emergency, such as during the disastrous earthquake it is possible to enter by destroying the key.

Kii-Tanabe Station has been designated as the tsunami evacuation building by Tanabe City and has been published on Tanabe City's website.[4] In addition, in order to be well known that it is designated as the tsunami evacuation building, some signs have been posted in the station building office part. (Fig.6)

(1) Place of signs

(2) Sign 1

(3) Sign 2

Fig. 6 Signs of the tsunami evacuation building

3.3 Consideration for resilience after the disaster

In the event of damage, mechanical equipment and electrical equipment that require time to procure and repair were installed on the upper floor higher than the standard water level, giving consideration to the recovery life after the disaster.

(1) Machinery and equipment (air conditioning outdoor unit, etc.):2nd floor
(2) Electrical equipment (power receiving, substation equipment, etc.): Rooftop

4. Structural safety

4.1Target performance of structure

The target performance for structural safety is basically based on the Building Standards Act. On the other hand the structural safety against seismic safety and tsunami in particular has been determined as follows.

(1) In the large-scale earthquake, it can be used only for minor damage and continued use:
(Importance factor is 1.25)
(2) The wave force caused by the tsunami prevents collapse, fall, or lift up.。

4.2 Design for tsunami loads

4.2.1 Design Policy

The one-story part (the concourse area) and the three-story part (the office area) were separated by an expansion joint, and the three-story office part was planned as the tsunami evacuation building. The foundation was planed cast-in-place concrete pile for the fall and sliding measures. Structural safety for tsunamis was examined in accordance with ” Matter to establish the safety structural methods against the supposed tsunamis in tsunami prone areas (Ministerial Public Notice No. 1318) ”[5] and " Practical Guide on Requirement for Structural Design of Tsunami Evacuation Buildings”.[6] The study flow, shown in Fig.7.

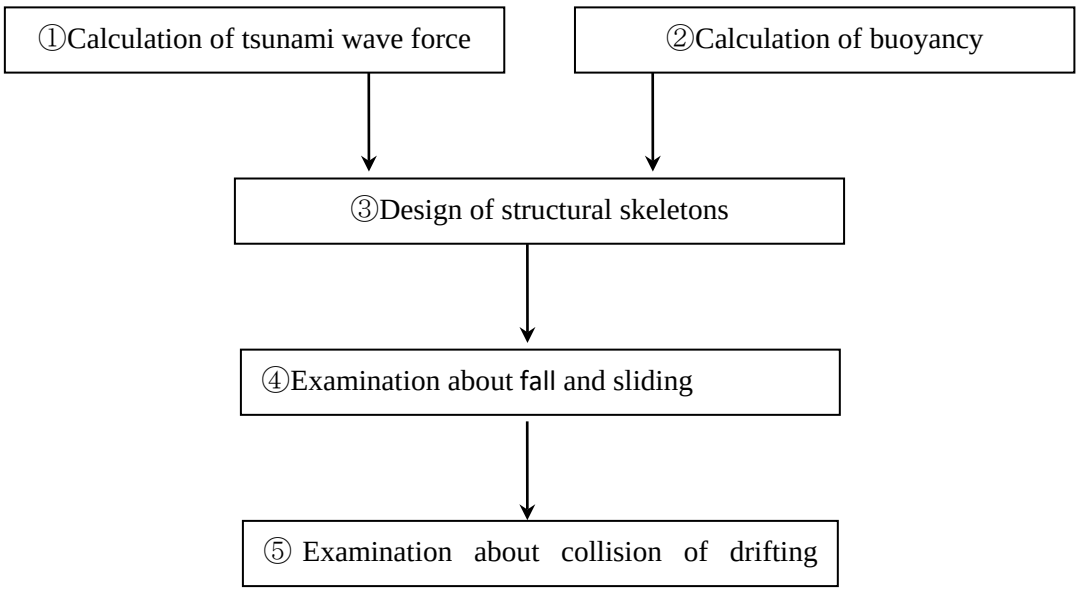

Fig. 7 Structural design flow

4.2.2 Calculation of tsunami wave force
Calculation formula of the tsunami wave force is formula (1).

$$Qz = \rho g \int_{z1}^{z2} (ah - z) B dz \tag{1}$$

Qz : tsunami wave force in the direction of travel for structural design（kN）
ρ : density of seawater（t/m^3）
g : gravity acceleration（m/s^2）
h : depth of inundation for design（m）
※－The reference water level is 2.9m at the Kii-Tanabe Station
z : height from the ground（m）
a : water depth coefficient（m）
※Because Kii-Tanabe Station is more than 500m away from the shoreline or rivers, and other facilities are expected to reduce the tsunami wave force, it is 1.5.
B : width of the pressure receiving surface of the part
z1 : minimum height of the pressure receiving surface（$0 \leqq z1 \leqq z2$）
z2 : maximum height of the pressure receiving surface（$z1 \leqq z2 \leqq ah$）
※No reduction due to opening

4.2.3 Design of structural skeletons
In the structural design of the building for tsunami load, consider the combination of loads shown in Equation (2). In addition, in the case of considering the fall of the building, sliding, etc., consider the influence of buoyancy due to the tsunami.

$$G+P+T \tag{2}$$

G : permanent load (dead load)
P : imposed load (live load)
T : tsunami load

In the combination of Equation (2), each direction, in each floor, the horizontal strength of the structural framework, to confirm by Equation (3) that the horizontal load or more of the tsunami.

$$Qui \geq Qi \tag{3}$$

Qui : horizontal load-carrying capacity of each story (i-layer)
Qi : required value of horizontal load-carrying capacity of each story (i-layer)

4.2.4 Examination about fall and sliding
In order to prevent the fall of the building, to confirm that the fall moment generated by the tsunami load does not exceed the resistance moment due to its own weight (considering buoyancy) and pulling strength of the pile containing the foundation weight.
In addition, in order to prevent sliding of the building, it is confirmed that the horizontal load acting on the pile by the tsunami load does not exceed the total value of the end shear strength of the pile (considering the reduction of axial force by pulling out at the time of buoyancy and fall).

4.2.5 Examination about collision of drifting objects
It is assumed that any of the outer pillars are destroyed by the collision of the drifting object, to confirm that the long-term axial force that the outer pillar was borne to the adjacent pillars can be transmitted. Furthermore, to confirm that the adjacent pillars can bear the axial force after transmission.

4.2.6 Results
As the result of the above study, it was confirmed the structural safety required for the tsunami load assumed.

5.Construction

5.1 Features of the construction plan
The station may not be closed for reconstruction work. In addition, due to the constraints of the site conditions, it is difficult to provide the temporary equipment. Therefore, it was a construction plan to repeat the partial removal and new construction.

5.2 Construction step
Specific construction procedures are shown below.
step1 : Removal of warehouses

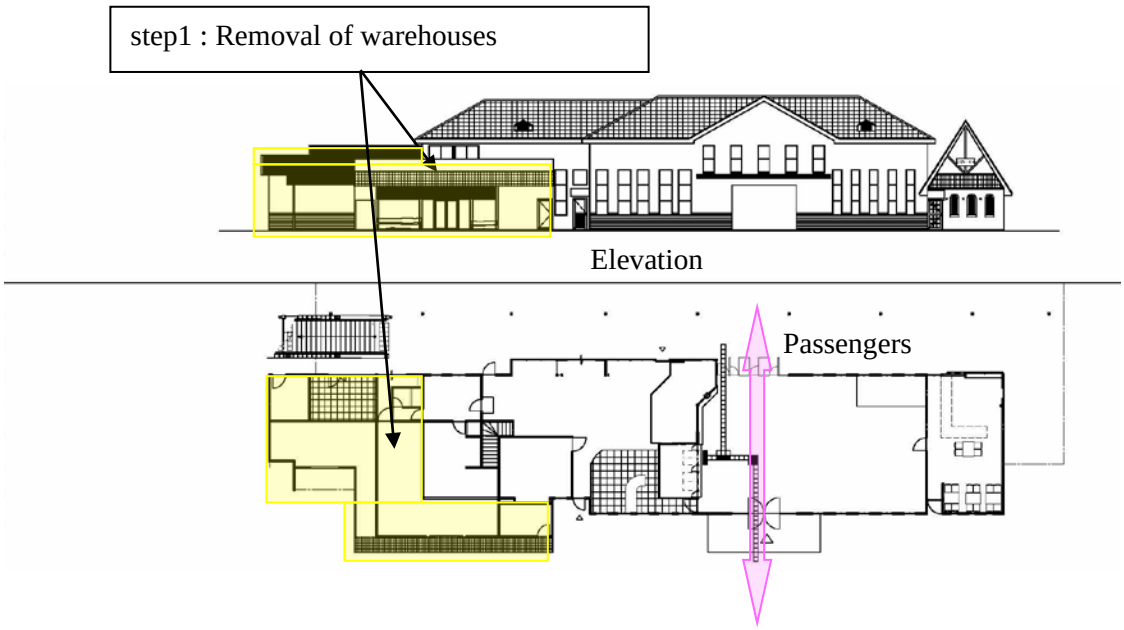

Fig.8 Step1

step2 : Construction of the office area.
(Tsunami evacuation building - disaster prevention base)

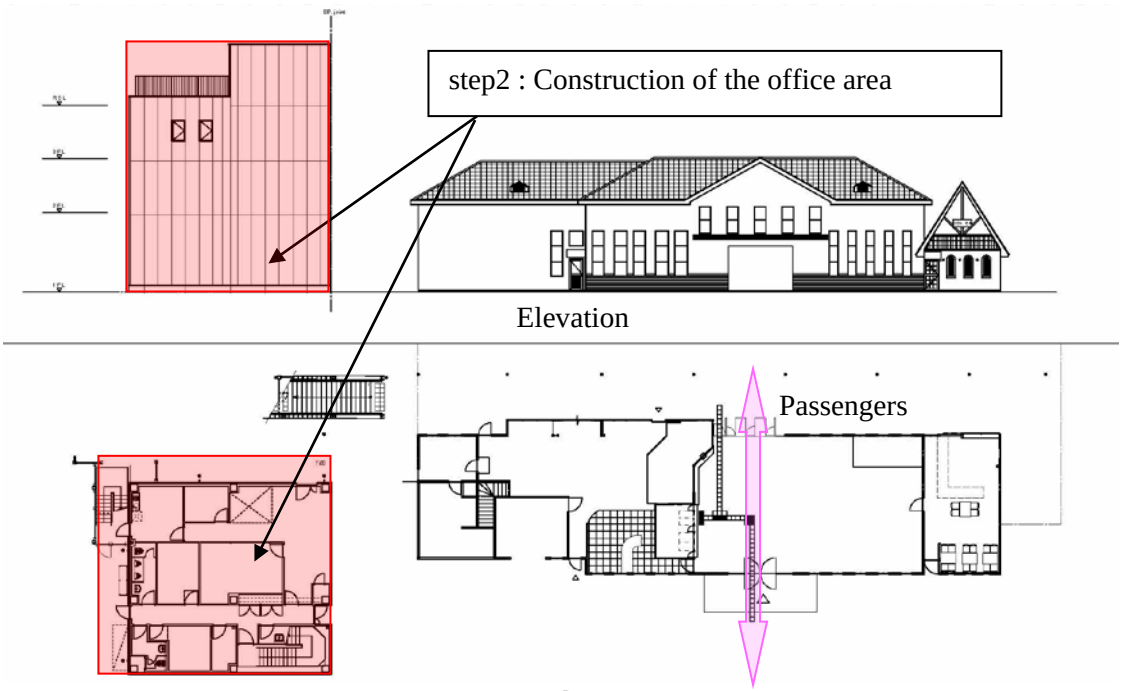

Fig.9 Step2

step3 : After the start of use of the office area, the removal of the old station office area

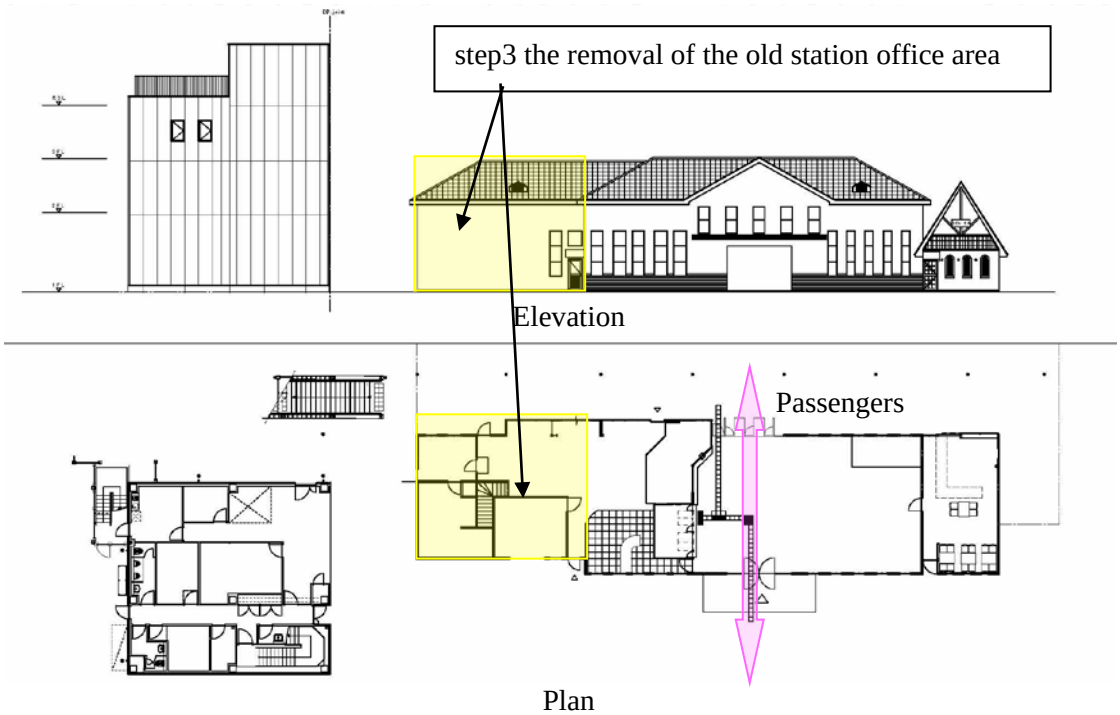

Fig.10 Step3

step4 : New construction of the station customer service part

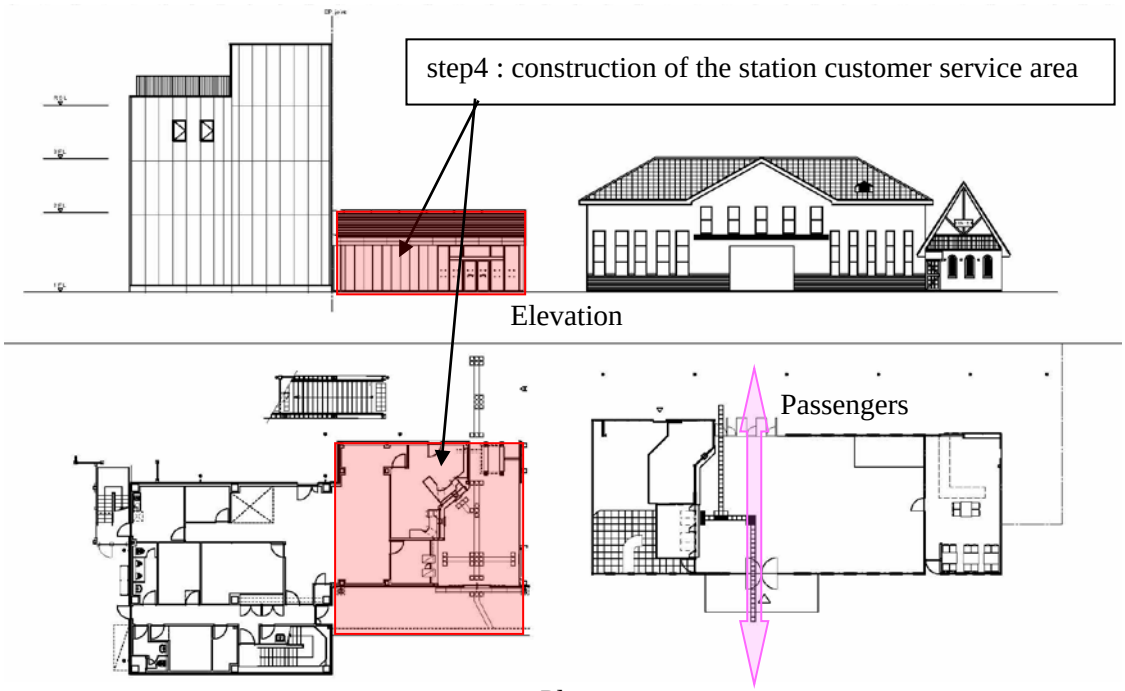

Fig.11 Step4

step5 : After the start of use of the station customer service part, the removal of the old station concourse (waiting room, store) part

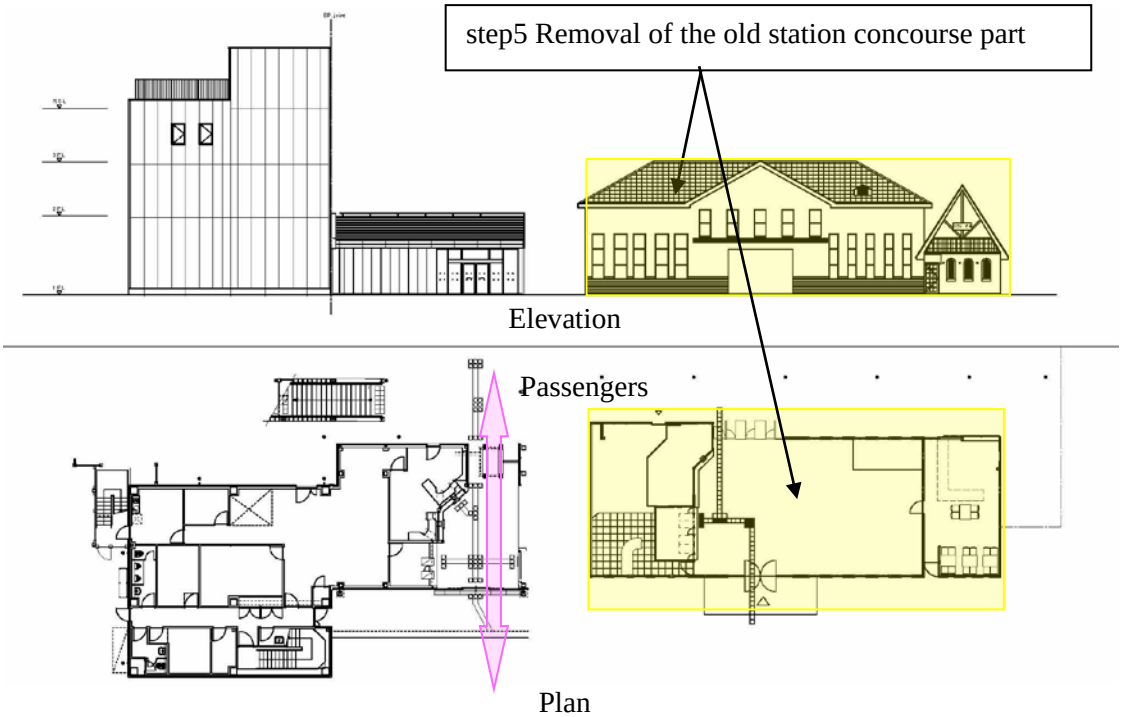

Fig.12 Step5

step6 : New construction of the station concourse part. →Completed

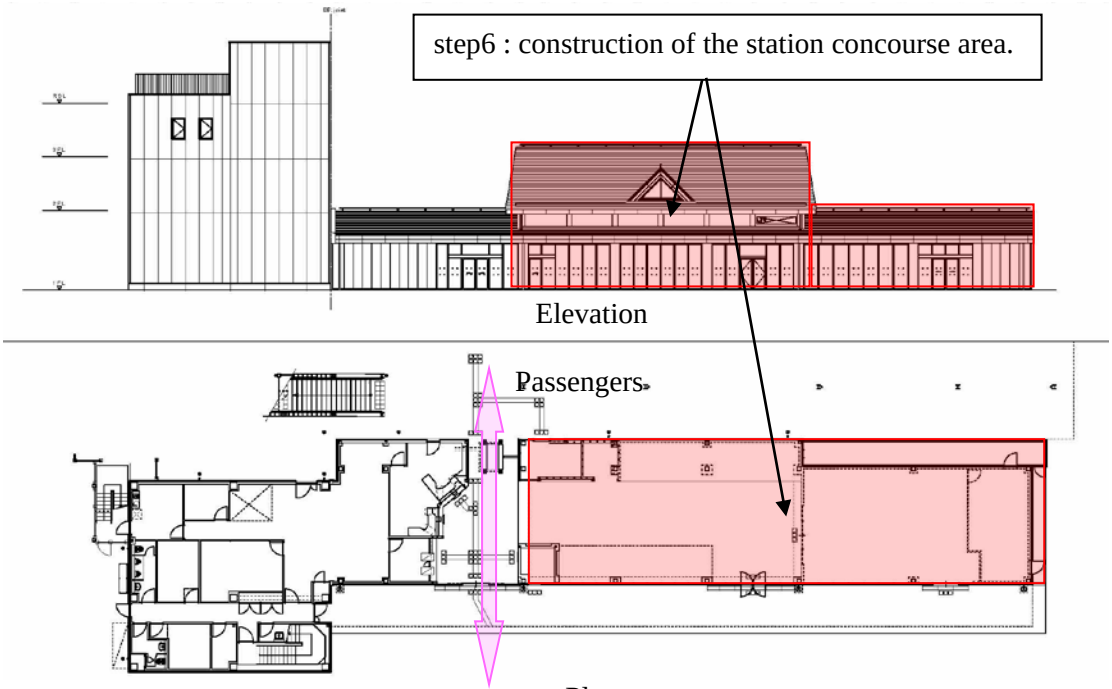

Fig.13 Step6

6.Summary

In the renovation of Kii-Tanabe Station, the plan was made in consideration of not only the convenience and comfort of station users, but also tsunami countermeasures (tsunami evacuation building). It has the functionas as an emergency evacuation site in the event of the disastrous earthquake (tsunami) and as a disaster prevention base after the disaster.

7. References

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[5] Ministerial Public Notice No. 1318, Matter to establish the safety structural methods against the supposed tsunamis in tsunami prone areas, 2011

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