Planning for YTIT Shaking Table of Two Horizontal Directions

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***Abstract*—Outline of two horizontal direction shaking table which is planned by YTIT is described. The shaking table will be used for seismic test of structures, student education. Table dimension 6m by 6m. Table displacements X and Y are ±20cm. Maximum power in X, Y direction is 30ton.**

Keywords—Shaking table, Two horizontal Direction, Earthquake, Hydraulic, Structure

I. INTRODUCTION

Uzbekistan is an earthquake-prone country. The Fergana region often feels earthquakes. In recent years, there was a magnitude (M) 6.2 earthquake in the Fergana Valley on July 20, 2011, killing at least 13 people and injuring 86 people due to the collapse of houses. On April 26, 1966, a near field earthquake of magnitude V occurred in Tashkent, causing great damage to the city[1]. Large earthquakes have also occurred in neighboring countries Kyrgyzstan, Tajikistan, Turkmenistan, and Afghanistan, which could affect Uzbekistan.

Because of the Armenian earthquake in 1988 during the former Soviet Union, a reaction force wall for seismic testing was made at Turin Polytechnic University in Tashkent(TTPU). Experiments using this facility are also being conducted. In addition, a device for experiencing earthquake motions was made by the Ministry of Emergency Situations around 2015. In addition, TTPU has assembled a self-made one horizontal direction shaking table for structural experiments and is conducting experiments. Considering the importance of seismic design of structures and the need for structural safety education, YTIT decided to plan and promote two horizontal shaking table that is one step ahead of TTPU, recognizing importance for shaking table educational effects.

Fig.1 1966 Tashkent Earthquake Damage (by the website of https://sputnikimages.com/media/728747.html)

Fig.2 Educational Shaking Table Test in Peru Catolica Uni.

II. SHAKING TABLE

It is estimated that vibration tests of the structure would be conducted after the Industrial Revolution. A vibration test device[2] was made by an Englishman who came to Japan in the wake of the Nobi earthquake that occurred in Japan in 1891. In the United States, a shaking table was built at Stanford University after the 1906 San Francisco earthquake.[3] After the war, model experiments on an electric shaking tables were conducted. In addition, hydraulic servo technology has been applied to shaking tables, and since the 1950s, shaking tables

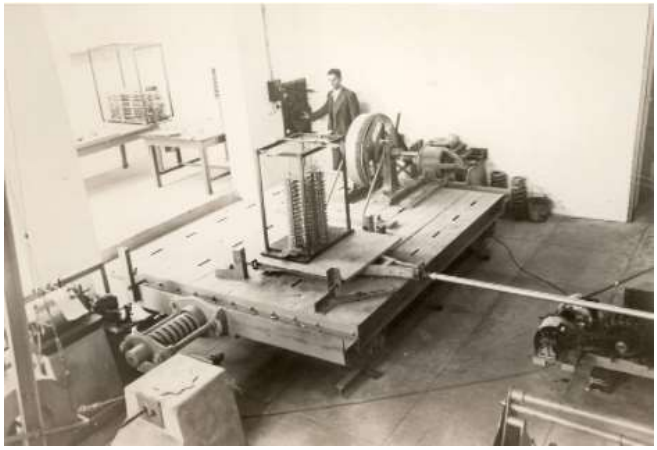

Fig 3 Shaking Table of Stanford Blume Center in1906 San Francisco Earthquake

have been used in many American engines. In Japan, a 12m square [4] and 20m x 15m shaking tables were completed in

1970 and 2005[4]. Since then, shaking tables have been used all over the world. In addition to electric linear motors and hydraulic servo drive devices, various drive control devices such as AC servo motors are used in response to the fact that a large displacement of several meters and a large speed of several m / s have been revealed.

Fig.4 Largest Shaking Table (20m x 15m) of X-Y-Z 3D

YTIT HORIZONTAL TWO-DIRECTION SHAKING TABLE PLAN

A YTIT Plan of two horizontal direction shaking table (called YTIT shaking table) is with a focus on seismic properties for structures. YTIT purposes for shaking table construction are to experience the hydraulic machine manufacture, machine electric control, data analysis, and to understand the structure vibration, foundation responses to shaking table reaction.

YTIT requests are Drive System: Hydraulic Electric Control System, Table dimension: 6 m × 6 m, Guide Bearing of linear guide bearing system (THK company). YTIT is located in a densely populated area. When the shaking table drives, reaction force of shaking table moves the foundation and gives vibration to the surrounding area. In order not to affect the surrounding area, the method of supporting the foundation with pneumatic springs is widely adopted, as shown in Fig. 5. YTIT' also plans to adopt this pneumatic spring method.

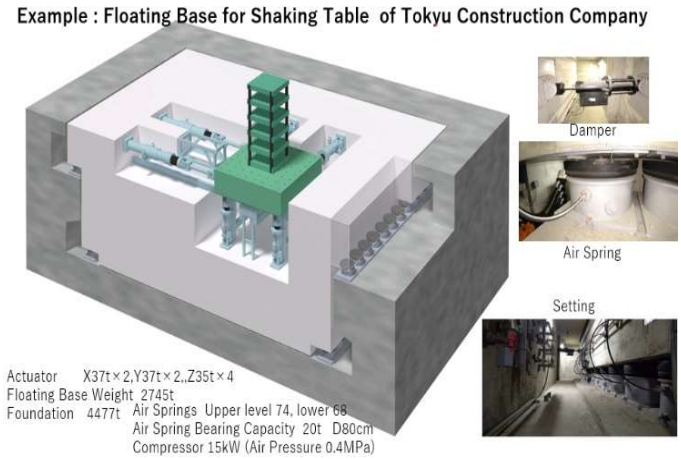

Fig.5 Base Isolation for Shaking table foundation (Tokyu Co.)

According to YTIT requirements, and considering YTIT and Uzbekistan situation, also other shaking table specifications in world, a recommended specification to YTIT shaking table was made like follows.

TABLE I. YTIT SHAKING TABLE SPECIFICATION

Drive System	Hydro-electric control drive
Shaking Direction	Two Horizontal X, Y Directions
Table Dimension	6m x 6m
Displacements	±20cm in X, ±20cm in Y
Velocity	100cm/s in X, 100cm/s in X
Acceleration	1G with weight, 2G no weight in X, Y
Table Weight	15ton
Over Turning Moment	75tom・m
Supply Oil Pressure	210kg/cm^2

Actuator is swing actuator, has double piston rods. Four same horizontal actuators are used for the shaking table. Two actuators are installed in X direction, also in Y direction. A actuator has the out-put power of 15tonf with piston area 84cm^2 (cylinder inner diameter 12.3cm, piston rod diameter 7cm) and supply oil pressure 0.85×210kg/cm^2. In order to correct the cross talks by two direction actuators, the strokes of actuators must be longer than the table displacements. The cross talk is explained in Fig.6. In YTIT shaking table, the actuator stroke of 44cm will be adopted. Actuator length is

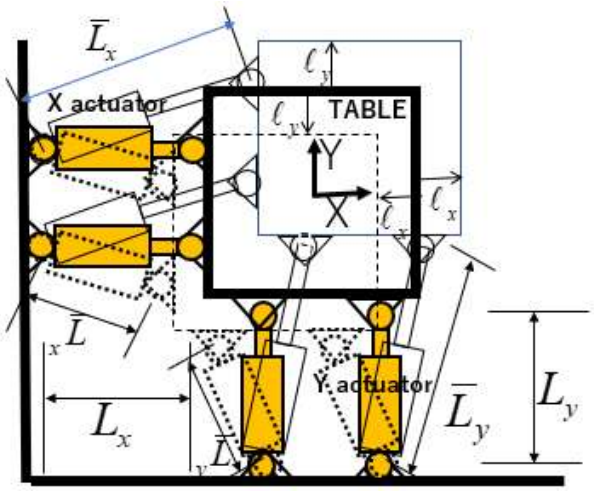

Fig.6 Cross Talk between X and y Actuators in Shaking Table.

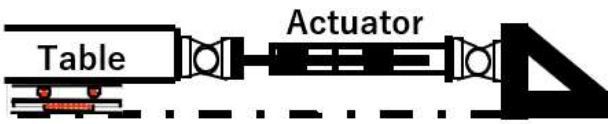

Fig. 7 Actuator connected with table by using ball joints. about 150cm.

Space between table and reaction frame for actuator setting will be about 220cm ±22cm, as shown in Fig.7. Actuator weight will be 550kg. load to axial drive will be 150kg approximately, load to lateral drive will be about half of actuator weight.

Table weight is calculated 11.8tons with steel plate thickness of 14mm.Table height of Z direction is not necessary to be large in comparison with three-dimensional shaking table because of no Z direction excitation. Table height will be

0.5m. Table up-lifts may be occurred at tests of high-rise model structures. The gravity center height of 5m with test weight 15ton will cause an over turning moment and make a table up-lift. Table weight and test structure weight will resist the over-tuning moment. The shortage of resistance to the overturning moment is supplied by the up-lift preventing device. The device would be required. After completion of shaking table, it is possible to install the devices. Fig.8 explains the table and its accessories.

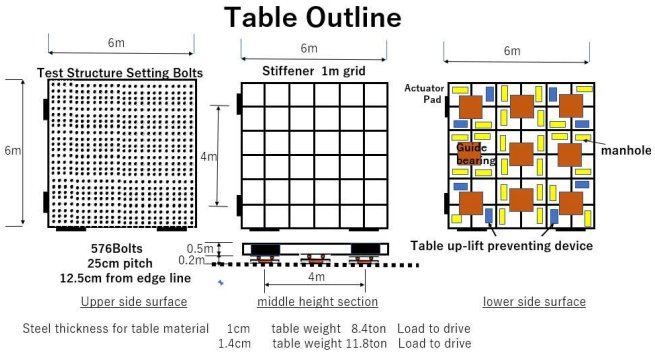

Fig.8 Table and Its Accessories

hThe table have to supported by two horizontal direction bearings. The bearings will resist yawing moments and guide the table linearly along X and Y directions. The bearing dimension is 1m x 1m x 0.2m. Nine sets of bearings are installed between table and foundation. Shear resistances for X and directions are 5tonf each. Total plan yawing resistances is 40ton x m. The load to drive is 2.3 ton. Outline of two horizontal direction bearing is shown in Fig.9. YTIT requires bearings of THK Company. Fig.10 is the photo of THK Company two horizontal bearing for base isolation buildings.

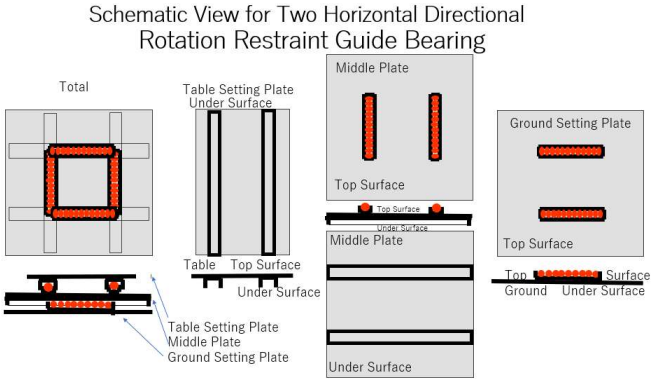

Fig. 9, Outline of Two Horizontal Direction Bearings

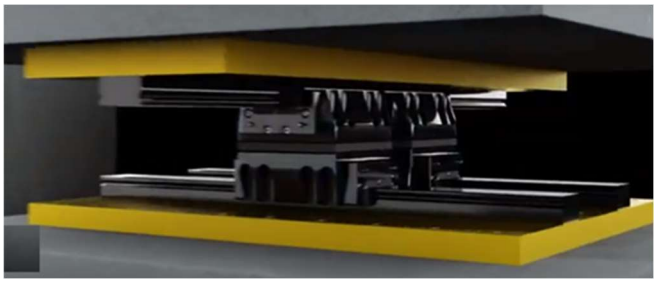

Fig.10 Two Horizontal Direction Bearing of THK Company

Hydro-electric control actuator has servo valves through manifold block, which control pressured oil flow. Servo valve capacity (500 ℓ /min) is calculated by maximum velocity (100cm/s) and actuator piston area (84cm^2). The pressured oil accumulators using the pressured nitrogen gas are always equipped in the oil supply line and return line to absorb the pressure fluctuation and shock motions. At continual driving, the accumulator can work as the pressured oil supply. In the case of velocity drive V cm/s, the power supply will provide V×(2/π) cm/s, and accumulator will provide V×(1-2/π) cm/s. For YTIT shaking table, continual velocity drive of 20cm/s is required in X and Y directions simultaneously (40cm/s in one direction). Power supply capacity will be calculated as 88Kw→90Kw by discharge oil capacity 4 × 20×(2/π) ×84cm^2 ×60sec=257ℓ/min and oil pressure 210kg/cm^2. Accumulators of 5 ℓ, total capacity 20 ℓ will be equipped near actuators. If large velocity will be required, the accumulator bank will place near power supply. In the case of 100cm/s velocity (one sin wave of 1Hz, pressured oil volume 17.2ℓ) request, the accumulator bank of 400 ℓ(discharge 18.8ℓ with 120kg/cm^2 nitrogen gas) will provide duration 1second with sin wave of 100cm/sec. Oil must stay in tank for more than three minutes in order to remove cavities in oil liquid. Continual drive of velocity 20cm/s in sinusoidal wave will require oil volume of 770ℓ, accumulators 180ℓ, pipe or hose 200ℓ(stream velocity 4m/s in pipeline). So, total oil volume would be about 1.15m^3. Tank capacity will be 1.5m^3. Temperature of pressured oil will increase along with drive time. Heating value of the shaking table will be 1.41× 210 kg/cm^2×257ℓ/min=76,098kcal/hour. Oil temperature increase during drive ΔT will be given as ΔT=1.41×76098/(860×1150×0.87×0.45)=2.8℃/min. In case of shaking table drive minute time T, Oil temperature increase is ΔT×T=2.8T℃. So, if shaking table will be driven for 10min., oil temperature would increase to 28℃. The situation is not good. Oil cooling system of enough capacity to continue shaking table drive, must be installed. Fig. 11 is the schematic plan of hydraulic power supply in YTIT shaking table.

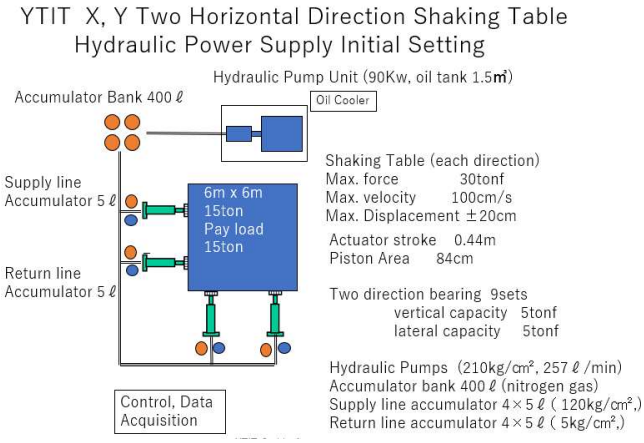

Fig.11 Schematic for YTIT Two Horizontal Direction Shaking Table Power Supply

Block diagram of total system for YTIT two horizontal direction shaking table is shown in Fig.12. YTIT Total system will be prepared by extending the system of one horizontal direction shaking table in TTPU (Turin Polytechnical University in Tashkent) to two horizontal directions[5,6]. TTPU system has one actuator control system. YTIT system has four actuator control systems, shown as Fig.12. Synchronization for actuators is controlled with each input signal. Input signals of time series for shaking table are made in a personal computer (PC). Cross talk will be corrected with input signals in PC. If interaction effects between shaking table and test structure (specimen) will be requested to correct,

input signals would be modified in PC. Shaking table response will be effected by the frequencies (33Hz: table, 23Hz with test structure) which are composed with the shaking table loads (table load 15t, with test structure 30t), and the oil column spring $\beta A^2 /V$=673t/cm (β: volume elastic ratio 100ton/m^2, A: piston area of actuators, V: oil volume of actuators). Shaking table responses of higher than the frequencies will be decreased. Each input signal is analogized through DA convertor and to analog controller, then to solenoid driver, so solenoid moves valve spool with the feed-back control, controlled pressure oil moves the actuator piston rod. Position signal of piston rod is returned to analog controller and compared with input signal. Input signal to analog controller will proportional to displacement. Input signal to solenoid driver is proportional to velocity.

Limit performance of YTIT shaking table is shown in Fig.13 Many kinds of shaking table test will be conducted in the area of limit performance. There are many seismic strong motion data. YTIT shaking table will reproduce 1995 JMA Kobe records, and so on.

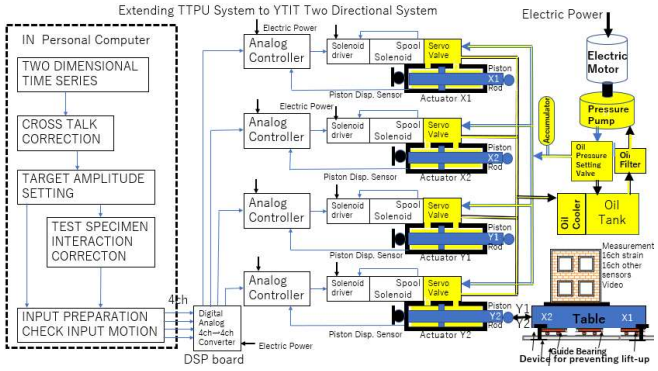

Fig.12 Block Diagram of YTIT Two Horizontal Direction Shaking table.

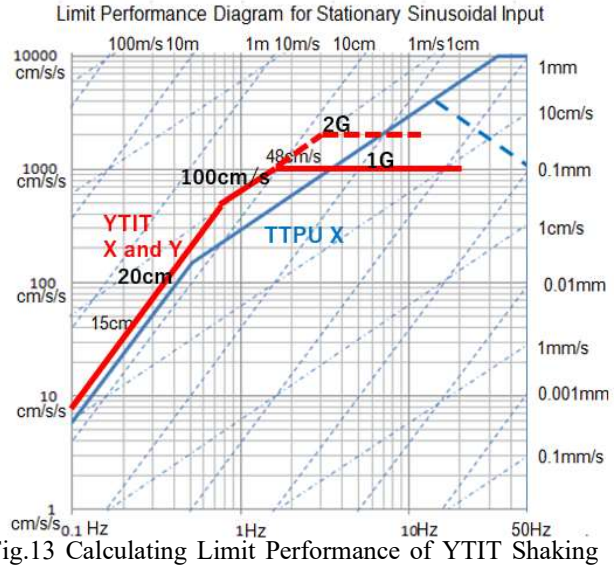

Fig.13 Calculating Limit Performance of YTIT Shaking Table

Test structure responses are measured by strain gages and accelerometers, displacement meters, etc., through amplifiers to AD converter. 16 channel data will be recorded.

YTIT shaking table will be constructed in YTIT campus, near lecture buildings. So neighborhood vibration must be mitigated as small as possible. Therefore, floating base (base isolation) will be adopted for YTIT shaking table. Floating base weight is about 1500ton, and maximum force is 30ton. Thus floating base response amplitude will be 0.02G. The vibration is absorbed in floating base, so neighborhood vibration will be negligible small. To float the 1500t base, air compressor 5kg/cm^2 , 10Kw will be installed. Shaking table facility has a floor area 19.1m x 19.1m, and overhead traveling crane of 20t will be installed.

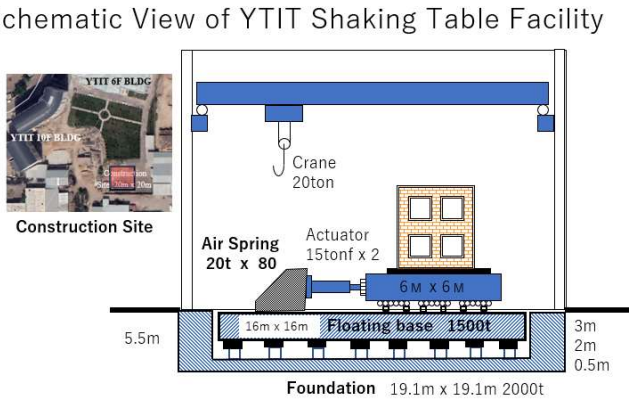

Fig. 14 YTIT Shaking Table Site, Facility and Floating Base

III. CONCLUSIONS

Rough design plan of YTIT shaking table which can move in two horizontal direction is described. Earth construction start is desired.

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