2-S-34

WAKEFIELD LABORATORIES LIMITED

44 WAKEFIELD STREET, AUCKLAND, NZ · BOX 5348 · TELEPHONE 30-189

REPORT

SUBJECT: SIMULATED EARTHQUAKE TEST

CLIENT: LOCKWOOD BUILDINGS LIMITED — DATE: 24 February 1969

ADDRESS: P. O. Box 520, — COPIES TO: Client (2) KRTA (1)

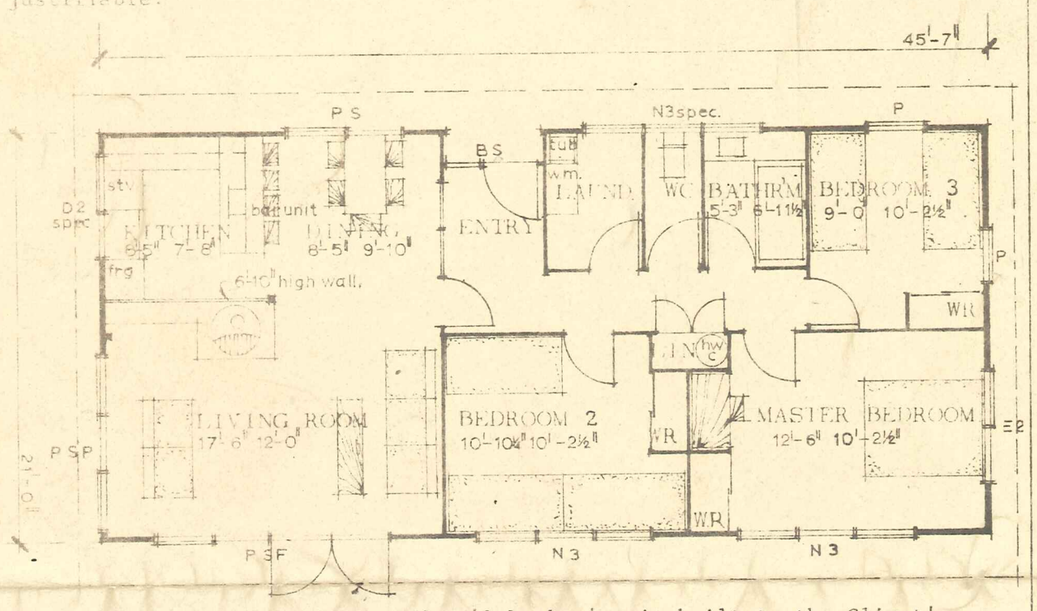
Rotorua. — JOB No: 559

STANDARD SPECIFICATION: N/A — CLIENT'S REF: Letter 30.9.68 Mr D.V. Brebner

CLAUSE	COMMENTS	RESULT

Wakefield Laboratories were asked to advise on simulating earthquake forces on a Lockwood house which had been erected in Rotorua. Recommendations had been made by the D.S.I.R. on the nature of the tests, and these were followed but extended to give a more comprehensive set of tests.

As earthquakes consist of random ground movements over a band of probable frequencies, it was considered necessary to apply a range of exciting frequencies to the house under test. The vertical component of motion associated with earthquakes was not simulated because the majority of the damage done by earthquakes is attributable to the horizontal movement only. Further, the expense of simulating vertical movement was not considered justifiable.



The house tested was a 1000 sq.ft. 'Suburban' unit built to the Client's 1969 specification of Tasman pine incorporating walls of 2⅝" thick aluminium sheathed 'Super Lamina' boards with provision for additional vertical tie rods in the interior partitions. These were used in the initial tests and dispensed with (by loosening the nuts under the floor on the ends of these tie rods) when it was found that they were not required. The dividing partition between kitchen and lounge was only 6'10" high and there was no partition between kitchen and dining room. The roof cladding was Decramstic tiles. The house was supported on top of 8" square concrete blocks, which were lying on their side on a concrete slab. Movement of the house at floor level was restricted, but not fully restrained, by timber props around the perimeter.

A 1½" thick timber ceiling was built in the entrance hall to support the earthquake simulating mechanism, which consisted basically of a 10 HP motor driving a centrally pivoted 6'0" long arm, which rotated in a horizontal plane close to the underside of the roof in the centre of the house. By bolting weights to the arm at various distances from the centre of rotation, a variable out of balance centrifugal force was generated, which was transferred to the walls of the house through the sarking (roof decking) from the steel framework of the earthquake simulator. The frequency of the out of balance centrifugal force was altered by changing the size of the pulleys on the rotating shaft.

Recording devices were fixed to the four corners of the building, so that a permanent trace of the movement at floor level and at roof level was obtained during each test. The position of door frames, window frames and corner posts, and the fit of doors and windows was noted before and after the tests.

A series of tests were made, the first six at 8.7 cycles/sec., with progressive increments in the out of balance force. The internal ties were loosened off for the last two tests in the first series, and no noticeable increase in the movement of the house was observed. These were followed by a second set of five tests which vibrated the building (without the internal tie rods) at different frequencies.

Attempts were made to estimate the fundamental natural period of the building and the level of the exciting force adjusted to limit the induced forces in the building to about 0.6 g. at any level in the resisting walls. However, it was found that the large forces generated were greater than could be fully restrained against movement at floor level, thus resulting in a system of more than one degree of freedom. At lower frequencies, the effects of the higher modes appears to be more significant from the plots of frequency versus amplitude.

The frequency/amplitude curve is plotted for an exciting force equal to 20% of the total weight of the building tested, including the floor. The dynamic magnification raises the shears induced in the walls to a level corresponding to at least 0.6 g. We estimate that shears of this order are likely to be induced under earthquake with ground accelerations of at least 0.3 g. such as were experienced at El Centro and also at the recent Inangahua earthquake.

At the 8.7 cycle/sec. series of tests, a plot of deflection versus exciting force approximates to a straight line, indicating a linear stress/strain relationship holds. Also shown on this plot is the estimated deflection at these static loads for a solid timber wall construction.

We consider that the series of tests covered the range of known frequencies of the ground motion, and simulated the level of ground accelerations that records show can be expected in earthquake zones. In addition, the tests were carried out with a range of frequencies which would ensure that the maximum response was generated in the building. The forces induced in a building in an earthquake depend, amongst other things, upon the distance of the building from the epicentre. In the tests we attempted to simulate conditions that would develop in the region close to the epicentre of an earthquake of the order of 6 to 7 on the Richter Scale, which would produce observed damaged levels on the Modified Mercalli Scale of 8 to 10 for a conventional wooden framed house.

Shear deflections at eave level of up to ⅝" horizontally were recorded at 5 cycles per second, with an out of balance centrifugal force of 5,630 lbs. The weight of the entire building was estimated to be 33,500 lbs. (including the floor), while the roof and upper 2/3 of the walls was estimated to weigh 20,500 lbs.

During the tests, window frames and wall sections vibrated and creaked in an alarming manner, but no residual damage could be detected. Windows and doors all continued to work satisfactorily at the end of all the tests. No damage was apparent in the roof cladding. It must be recognised that a real earthquake consists of a series of random pulses, whereas the tests consisted of a regular cyclic force. While it is possible that some residual deflection

might result under a real earthquake test, this would tend to be less than the maximum deflections which were recorded during the test. The nature of the construction is such that these deflections are easily accepted without causing secondary damage to finishes, which would make repairs necessary or make the house unusable.

The tests indicate that the Lockwood 'Suburban' unit is well suited for use in earthquake prone areas. A tendency observed that even the low foundations rock under earthquake tests, demonstrated the need for stable, well constructed foundations for any house, and bears out the observations that isolated pile foundations are an unsuitable form of foundation for houses in earthquake zones.

APPENDIX:

Attached are tables showing double amplitude deformations measured during each of the tests and the level of the exciting forces. Also appended are curves showing amplitude versus frequency of the vibration, and the load/deflection for excitations at 8.7 cycles per second.

TESTED BY: W.J.T.

CHECKED BY: L.O.H.

DIRECTOR: L.O. Hunter

TABLE OF DEFLECTIONS AT FOUR CORNERS OF LOCKWOOD 'SUBURBAN' HOUSE

FREQUENCY (cps)		5			7			8.7			11.6			13.1		
CENTRIF. FORCE (lb)		70lb @ 31½" = 5630			32lb @ 31½" = 5040			32lb @ 31½" = 7820			4 lb @ 31½" = 1730			8 lb @ 31½" = 4410		
POSITION		Top	Bott.	Diff.	Top	Bott.	Diff.	Top	Bott.	Diff.	Top	Bott.	Diff.	Top	Bott.	Diff.
N.W.	N.S.	0.60	0.15	0.45	0.35	0.20	0.15	0.30	0.10	0.20	0.15	0.10	0.05	0.20	0.10	0.10
	E.W.	0.70	0.35	0.35	0.20	0.15	0.05	0.35	0.20	0.15	0.20	0.10	0.10	0.15	0.10	0.05
N.E.	N.S.	0.40	0.15	0.25	0.25	0.10	0.15	0.30	0.10	0.20	0.10	0.00	0.10	0.15	0.00	0.15
	E.W.	0.60	0.35	0.25	0.20	0.10	0.10	0.30	0.20	0.10	0.20	0.00	0.20	0.15	0.10	0.05
S.E.	N.S.	0.50	0.15	0.35	0.20	0.10	0.30	0.15	0.15	0.15	0.10	0.00	0.10	0.15	0.00	0.15
	E.W.	0.60	0.35	0.25	0.20	0.10	0.10	0.30	0.25	0.05	0.20	0.05	0.15	0.10	0.10	0.00
S.W.	N.S	0.30	0.15	0.15	0.35	0.10	0.25	0.30	0.15	0.15	0.20	0.05	0.15	0.20	0.10	0.10
	E.W.	0.45	0.30	0.15	0.25	0.20	0.05	0.30	0.20	0.10	0.15	0.05	0.10	0.20	0.10	0.10
AV. DEFLN.	N.S.	0.300			0.162			0.175			0.100			0.125		
	E.W.	0.250			0.075			0.100			0.137			0.050		
DEFLN. FOR F = 0.5g	N.S.	0.883			0.538			0.370			0.961			0.470		
	E.W.	0.735			0.249			0.212			0.320			0.188		

NOTE - Amplitude = ½ Deflection

WAKEFIELD LABORATORIES LIMITED

WAKEFIELD LABORATORIES LIMITED