A few very old adobe or wood frame buildings in the Goleta area received serious earthquake damage. For example, a large unreinforced adobe residence located near Coal Oil Point on the West Campus of UCSB received serious damage to several bearing walls in localized areas on the second floor. The building was constructed around 1920. The oldest American-built structure in the Goleta Valley, a large multi-story wood frame building known as the "Stow House", sustained significant cracking of plaster walls in many rooms, but did not sustain serious structural damage. The building is mounted on a high foundation with long redwood joists and supporting piers, and was built in 1872.

7.2 Effects on Structures at the University of California, Santa Barbara

There are approximately 50 permanent buildings and a number of temporary buildings on the UCSB campus. Significant structural damage was sustained by at least 10 of the permanent buildings. It is likely that more serious structural damage was partly prevented as a result of a seismic review program recently instituted by the University. As part of this program, a review of the seismic integrity of all buildings on campus was performed by a consulting structural engineer (Mendes, 1973). Several deficiencies were identified in this review, the most serious of which were fortunately corrected before the earthquake. One such rehabilitated structure which received less than serious earthquake damage is North Hall. Following a brief description of soil conditions, construction history and overall structural damage on the campus, a description of the structural damage sustained by North Hall and several other buildings will be presented.

Soil Conditions

The following description of the underlying soils and foundation material at the campus site was given by Mendes (1973):

> The underlying natural soils consist of silty sand to depths of 10 to 17 feet, underlain by shale to depths in excess of 100 feet. The upper soils are moderately firm at (normally dry) moisture content but would become somewhat weaker and more compressible when wet. Water seepage is usually found in most borings at depths ranging from 6 to 17 feet depending on particular location, past fainfall, etc. In almost all instances, seepage occurs in the silty sand (and sea shell layer) immediately above the shale stratum. This results in a perched watertable against the shale formation. Generally, only one and two story buildings are supported on the silty sand.
>
> The underlying shale is firm to very firm, and usually no difficulty is experienced in penetrating the shale with conventional bucket-type drilling equipment. Some hard, cemented silicious layers are occasionally encountered which require jack-hammers or similar equipment to penetrate through them. Generally, buildings three stories and higher are founded in

the shale formation. Depending on the depth to the shale and foundation loads, conventional spread footings, drilled-and-belled caissons or straight drilled cast in place friction piles are used.

There has been very little heavy site grading except during the period of development at this general location of a U.S. Naval Facility in 1942. All permanent campus buildings have usually been sited within about two feet of existing natural grade.

Construction History

The permanent buildings on the UCSB campus were constructed during the 26 year period between 1952 and 1978. The design of each was governed by the earthquake safety requirements of the then contemporary edition of the Uniform Building Code. Buildings of the University of California are not required to conform to the earthquake resistance standards of public schools in California (Field Act, 1933).

The buildings are generally of Type I (fire resistive) construction, one to eight stories in height, wherein the floor and roof framing system are of reinforced concrete. Columns and bearing walls are usually of reinforced concrete, but some reinforced concrete block construction was utilized in a number of buildings constructed prior to 1962. The lateral force resiting system of almost every building is reinforced concrete or concrete block shear walls (Mendes, 1978).

Overall Structural Damage

The most common form of structural damage to permanent buildings consisted of moderate cracking of shear walls in the lower stories. The pattern of cracking was predominantly diagonal, with walls aligned along the north-south direction usually sustaining more severe damage than east-west walls. Such damage to reinforced concrete shear walls occurred most extensively in the Biological Sciences II, Engineering, Library III, University Center and North Hall buildings (see Fig. 3.2). In most cases repairs will consist of epoxy injection to rebond the cracked surfaces in the shear walls.

Among those buildings with concrete block shear walls, the most severe cracking occurred in Anacapa, Santa Cruz and Santa Rosa residence halls. Epoxy injection repairs are required in each hall. Sixteen shear walls in Anacapa and another sixteen in Santa Cruz were so badly damaged that replacement was necessary. However, the severity of damage sustained in these walls apparently resulted in part from the absence of grout around the steel reinforcement in some parts of the shear walls, and such other occasional deficiencies as missing or mislocated steel reinforcement, and inadequate laps and splices.

North Hall

North Hall is located at the south-east corner of Ocean and Campus Roads (see Fig. 3.2). The building is a three story reinforced concrete shear wall structure with plan dimensions of 240 feet by 34 feet. Photographs of the structure are shown in Figs. 3.4 and 7.3. A seismic joint isolates the structure from an adjoining building complex at the east end.

North Hall is of particular engineering significance for several reasons. First, as previously noted, a review of the seismic safety of the structure as originally designed and constructed (Mendes, 1973) revealed a serious deficiency in lateral load resistance which was corrected by the later construction of additional shear walls. These added shear walls conform to the earthquake resistance provisions of the 1976 edition of the Uniform Building Code. Rehabilitation of the structure was completed on May 13, 1976. Secondly, an extensive series of pre- and post-rehabilitation forced vibration tests were performed on the structure before the earthquake (Hart and others, 1978). The natural frequencies, mode shapes, and damping ratios in the fundamental mode were measured for translation in the north-south and east-west directions, and for torsion. The pattern of soil motion near the structure was also measured. Lastly, a very good collection of 9 strong motion accelerograms were recorded in North Hall during the earthquake, and are presented in Chapter 3 of this report. The peak structural acceleration of 0.94g recorded on the roof is among the largest ever recorded anywhere, as of this date.

Shown in Fig. 7.4 is the typical floor plan locating the shear walls in the structure in its rehabilitated form and also the interior and exterior columns. Details of the reinforcement of these shear walls are provided in Table 7.1. Shown in Figs. 7.5 and 7.6 are the east-west and north-south elevations, respectively. The new 24 foot long east-west shear walls are easily seen in the photographs of Fig. 7.3.

The building is founded on drilled and belled caissons. Allowable bearing pressure of the underlying soil is about 10,000 psf. The floor slab is 4 inches thick at ground level. The reinforced concrete floor and roof framing in the remainder of the building consists of a 2½" slab supported by concrete pan joists (Fig. 7.8) running the length of the building in the east-west direction. The joists are supported at about 24 foot intervals by the girders shown in Fig. 7.7 which run in the north-south direction between exterior columns. Full scale tests of this structure revealed that the floor slabs do not vibrate as rigid bodies, but rather they sustain significant in-plane deformation.

The structure has twenty interior and twenty exterior columns. A section through a typical interior column is shown in Fig. 7.9, and a typical exterior column in Fig. 7.10. The pattern of reinforcement is noted in the figures.

The construction of the roof is similar to that of the floor slabs, except that it slopes up from each edge at an angle of 32.2 degrees with respect to the horizontal.

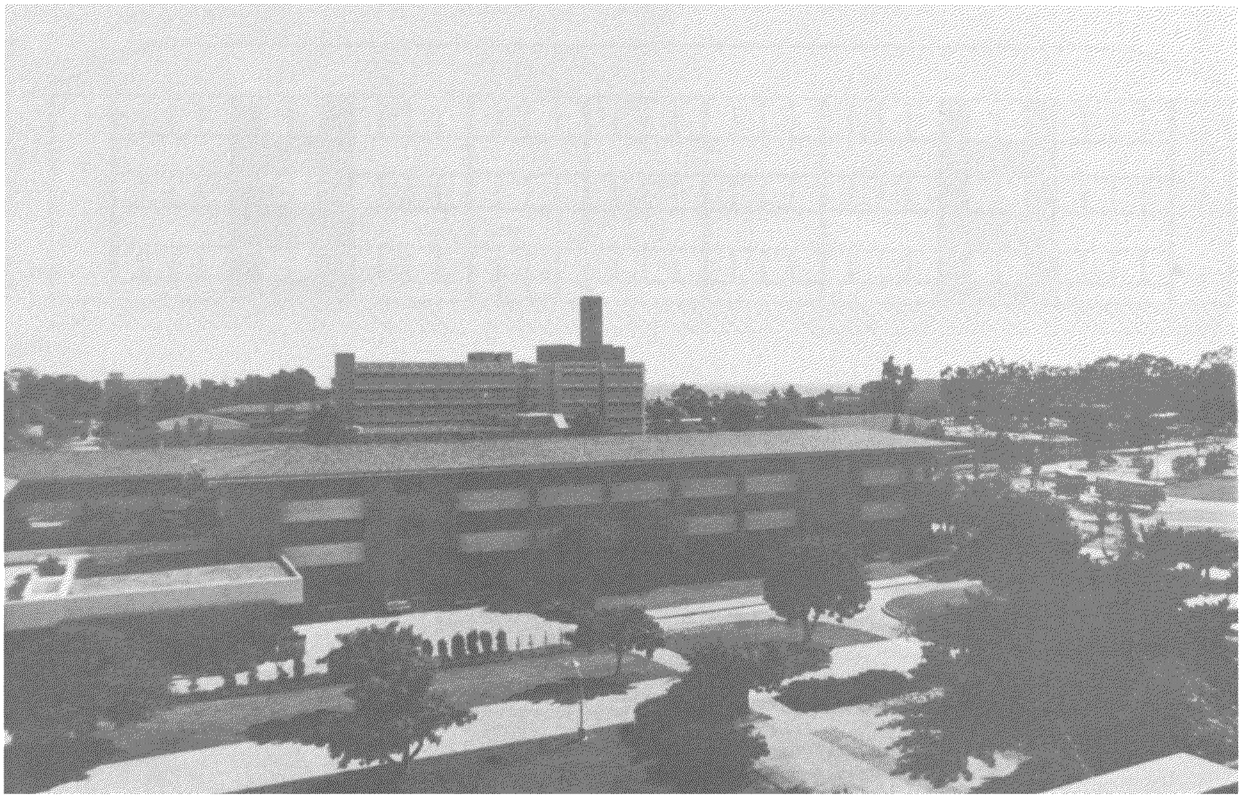

Fig. 7.3 East-west elevation of North Hall, UCSB, showing the east-west shear walls constructed during rehabilitation in 1976.

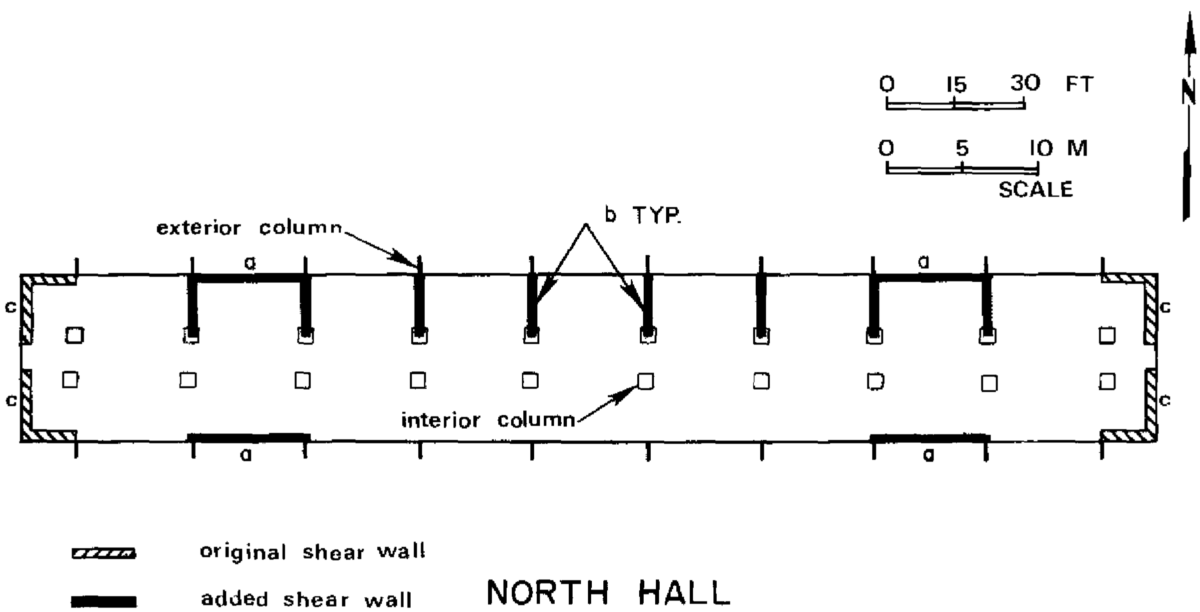

Fig. 7.4 Floor plan of North Hall, UCSB.