Relocation and Reconstruction of the Town of Barce, Cyrenaica, Libya, Damaged by the Earthquake of 21 February 1963

by

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Forward

The Kingdom of Libya with its northern boundary facing the Mediterranean Sea had previously been considered earthquake free and the earthquake of 21 February 1963 which almost totally destroyed the old town of Barce believed to have been founded by the Greeks more than two thousand years ago came as a complete surprise.

The writer went to Barce as UNESCO Expert from April to June 1963 upon the request of the Libyan Government and this paper presents a résumé of his findings and recommendations to the Prime Minister. He also drafted simple earthquake resistant regulations for the design and construction of buildings and structures in the Barce region, Cyrenaica, and other seismic zones in Libya and also prepared structural standard drawings for reinforced hollow concrete block construction for dwelling houses. (These regulations and drawings are not included in this paper.)

I. The Barce Earthquake

The initial damaging earthquake shock that shook the Barce Plain of northern Cyrenaica and caused serious damage to the ancient town of Barce occurred at approximately 19 hrs. 18 minutes, local time, on 21 February 1963. The information which the writer had obtained in Tokyo before going to Libya concerning this earthquake was as follows:

	Date	Time	Location	Depth	Magnitude
1.	Feb.21 d.	17 h.14m. 35.7s.	32.7°N, 20.9°E	h= 33Km.	M = 5.0
	(Time is GMT, standard time; add 2 hrs. for local time)				
2.	Feb.21 d.	18 h.33m. 06.8s.	32.9°N, 21.1°E	h= 30	M = 4.5
3.	Feb.21 d.	20 h.26m. 43.8s.	32.6°N, 21.0°E	h= 33	M = 4.4
4.	Feb.22 d.	02 h.47m. 21.0s.	32.9°N, 21.1°E	h= 33	M = small

(Numerous other shocks have occurred since then.)

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The data above were tentative ones published by the U.S. Coast and Geodetic Survey soon after the earthquake.

The epicenter of this earthquake may be considered to have been located in the vicinity of 32.7 degrees North latitude and 20.9 degrees East longitude. The focus (origin) of the earthquake is believed to be approximately 33 Km. below the ground surface. The magnitude, M, of the earthquake (measure of the energy released by the earthquake) has been estimated at approximately 5.0 but this could have been as high as 5.7. The epicenter (point on the surface measured vertically above the focus) is located approximately 13 Km. north-northeast of Barce and some distance west of Maddalena. The earthquake damage (intensity of the earthquake) to fort-like houses built in the past for agricultural colonists in this area has been noted to be very severe, about IX on the Modified Mercalli intensity scale.

There has been numerous earth tremors (after-shocks) since the damaging shocks which continue to this day. Recordings of these after-shocks could provide valuable information relating to seismotectonics of the region by installing proper seismic instruments at three or four locations as a minimum.

It may be of interest to note that the magnitude of the Agadir (Morocco) earthquake of 29 February 1960 was approximately 5.75 and the epicenter 2-3 Km. below the ground surface. Approximately 12,000 persons were killed and 12,000 wounded, out of the total population of 30,000 in this earthquake.

The Lar (Iran) earthquake of 24 April 1960, with a magnitude of 5.75, caused the death of 400 persons and destroyed 75 percent of the town of Lar. Subsequent earthquakes in Iran, namely, the Lar region earthquake of 11 July 1961 and the Qazvin earthquake of 1 September 1962, have caused tremendously large losses in lives and property.

Many earthquakes originate under the Mediterranean Sea and on the European side which have caused and may be expected to cause damage to man-made structures in the future.

The seismicity of northern portion of Cyrenaica along the sea coast from north of Benghazi eastward toward the Gulf of Bomba between Derna and Tobruk is suspect. The region of Cyrenaica north of approximately 32.2 degrees north latitude, which takes in both Barce and Beida, may be considered as seismically active and planners of construction in this region should consider the consequences of earthquakes that may occur in the future. Earthquakes strike without warning and require permanent precautions, if loss of lives and damage to property are to be avoided. Also, where earthquakes have occurred, earthquakes will recur.

II. Observations on Damage to Buildings and Structures

The damage caused to buildings and structures in the town of Barce and nearby areas is briefly described below.

a. Construction using rubble stone embedded in mud or clay (terra rossa) suffered extensive damage and is not earthquake resistant.

b. Construction using sandstone, limestone or other type blocks jointed in lime-cement or cement or cement mortars not properly reinforced with steel bars was vulnerable to earthquake damage and presents a serious potential danger to occupants of this type of buildings. The blocks should be dowelled and cramped together as the Romans did in their construction. This may be seen by samples in the Museum in Tripoli and at Leptis Magna, so that they will not fall apart in case of earthquakes. The heavy weight of the blocks is also a disadvantage from the viewpoint of earthquake resistance.

c. Construction using hollow concrete blocks for one storey dwelling houses suffered only moderate damage, although they were not reinforced. By making certain structural modifications in the design and construction and also using improved type of blocks, dwelling houses of this type of construction may be made to possess adequate degree of earthquake resistance.

d. Construction using reinforced concrete frames (foundations, columns, girders and slabs) with filler walls of sandstone and other type blocks performed well and escaped serious structural damage, although the walls were cracked and will require repair and/or replacement.

e. Buildings and structures of reinforced concrete and steel construction, such as the five storey silo building near the railway station and the elevated water tank of reinforced concrete, supported by the 25 meter tower, and other tanks of steel construction in the Barce region were undamaged. Those structures that were well designed and carefully constructed withstood the earthquake forces with no damage.

III. Earthquake Resistant Regulations

The experience gained at the sacrifice of approximately 330 human lives lost and heavy property damage indicates the desirability of applying earthquake resistant regulations to govern the design and construction of buildings and structures in the Barce region.

Antiseismic regulations have been prepared by the writer for consideration by the Government, entitled "Recommended Earthquake Resistant Regulations for Design and Construction of Buildings and Structures in the Barce Region, Cyrenaica, Libya". These regulations, based on the constant acceleration method of design, have been suggested as being best suited to local conditions and easy to apply and enforce. These regulations are valid for buildings up to say 5 or 6 storeys in height and it is anticipated that practically all buildings in the reconstructed Barce will be within this limitation. For taller buildings or towers (say more than 30 meters), their relative rigidity or flexibility must be taken into account and antiseismic design regulations need to be modified. The earthquake force, F, to be used in the design is determined from the following formula:

$$F = CW$$

Wherein C = design seismic coefficient varies from 0.06 for good soil conditions to 0.09 for poor soil conditions.
W = live and dead loads for antiseismic design.

The allowable stresses for building materials including foundation soils to be increased by one-third when seismic effects are combined with vertical load effects. The quantitative values for the live loads, wind loads, and allowable unit stresses for various building materials and foundation soils for normal vertical loadings should be those used by engineers who are familiar with local conditions. For this reason, quantitative values for the items mentioned above were not indicated.

IV. Recommended Construction in Seismic Areas

Inspection of the damaged buildings in the Barce region and the assessment of the data seem to justify making the following conclusions in regard to different types of construction:

a. Construction using rubble stone embedded in mud (terra rossa) suffered the heaviest damage and the collapse of these buildings was responsible for most of the casualties. This type of construction is not earthquake resistant.

b. Construction using sand stone blocks or rubble stone jointed in lime-cement or cement mortar suffered considerable damage. This type of construction is not earthquake resistant even when the walls are thick. On the contrary, the heavy weight of the blocks is a distinct disadvantage from the point of view of earthquake resistance because the earthquake force is proportional to the weight of the building. This type of construction should be avoided in seismic areas unless properly reinforced and made anti-seismic.

c. Construction using hollow concrete blocks for popular dwelling houses suffered only moderate damage. It is recommended that improved types of hollow concrete blocks be used and adequate vertical and horizontal steel bar reinforcement be provided to make the construction earthquake resistant. The blocks should be designed and manufactured in such shapes and dimensions to allow easy placement of vertical and horizontal steel bars and the hollow cores be made of sufficient cross-section so that the steel and cement mortar may devlop sufficient strength in bond to resist the stresses created by the earthquakes. The roof system using prefabricated reinforced concrete shell boards - the "DC" system - has been suggested by Mr. W. Podwapinski, UN Housing and Planning Adviser to the Development Council and has the advantage of not requiring wooden forms for pouring concrete which is an important consideration in Libya where timber is not abundant.

d. Construction using reinforced concrete space frames (foundations, columns and girders, of reinforced concrete) did not suffer structural damage. This type of construction is recommended for buildings of more than one storey. The roof and floor slabs should preferably be of reinforced concrete of sufficient strength and rigidity. The use of reinforced concrete walls for the exterior and for some interior partition walls has been found to be very effective in resisting seismic forces and the use of these seismic bearing walls is an indispensible feature of antiseismic construction in Japan.

The blocks of different types used for exterior walls and interior partitions are less effective than reinforced concrete walls, especially when the blocks are not tied or dowelled together. It is recommended that the common practice of piling the blocks up in mortar without reinforcement be replaced by reinforced block masonry construction.

The use of unreinforced sand stone blocks in building construction was prevalent but, as has been pointed out elsewhere, such construction presents a potential danger by falling apart in earthquakes. It is suggested that investigations be carried out to develop better construction systems, utilizing local materials.

e. Reinforced concrete or steel construction is recommended for important buildings and structures. Those of these types of construction in Barce resisted and withstood the recent earthquake without structural damage.

The above recommendations are believed to be not excessively severe. If enforced loss of life and damage to property from any future earthquakes may be minimized.

One storey dwelling houses of reinforced hollow concrete block construction may be built without presenting structural calculations, provided the construction satisfies the essential requirements for this type of construction.

For larger, important buildings, generally accepted methods of structural analysis and design should be used. Standard text books on structural engieering describe methods of analysis and design for lateral loads (wind and earthquake forces). In the book entitled "Structural Design for Dynamic Loads" (McGrow Hill Book Co., 1959), the writer has explained some of the methods currently in use, with special emphasis on Japanese practice.

V. Relocation of Barce

The technical and practical considerations favouring the selection of a new site for rebuilding the town of Barce were described in the first report to the Libyan Government. The writer continues to be of the opinion that a new town of Barce be built near to the present town but on higher land. The area to the west of present Barce gradually rises in elevation and it is recommended that a suitable tract of land sufficient to accommodate the new town be selected in this region. The area referred to is bounded on the north by the highway from Barce to Benghazi via Tocra and on the south by the railway from Barce to Benghazi. The elevation of the present town of Barce is approximately 280 meters above sea level and the temporary (or semi-permanent) lake of El Gurigh to the north-east of Barce is uncomfortably near.

A new site which satisfies the requirements of better soil and geological conditions than the present site with the elevation ranging from 280 to 300 meters is recommended. Reconstruction of Barce on state owned land would present least difficulties. However, should construction on privately owned land near to the present town of Barce be deemed desirable by the new town plan, as well as offering the possibility of utilizing some rehabilitated buildings and facilities in the old town, this should not present unsurmountable difficulties in carrying out the reconstruction programme for Barce. The Government may negotiate an equitable arrangement with private owners, such as an exchange of land. The objections that landowners in the present town may have to relocating the new town on a better site may be overcomed by providing the landowners with land at the new site corresponding to the amount and kind of land they own in the present town, either with or without charge. The charge, if any, may be at a nominal figure. The arrangement for other earthquake victims should be on the same basis of Government assistance - not compensation - in making land available for reconstruction.

Among the advantages in building a new town based on a model; up-to-date town plan on clear land may be mentioned that a better town in the Barce Plain could become an attraction to tourism as well as contributing to the economic development of the region.

Among the objections to rebuilding on the present town site may be mentioned the fact that the time that would be required to condemn existing dangerous buildings, their demolition, removal of debris, etc. before reconstruction operations based on the new town plan of Barce could be commenced, may require too much time to meet the demand for quick reconstruction.

It is to be understood, however, that should government decision be taken to rebuild on the present site rather than to relocate the town to a nearby site, it would be possible from the engineering point of view to design and construct earthquake resistant buildings and structures to withstand earthquakes of the magnitude of the recent Barce earthquake. Future potential seismic hazards and the cost of constructing new buildings at the present site would be greater than on a more favourable site.

A word of caution in regard to damaged buildings in Barce may be justified. To the unexperienced eye, buildings that remain standing, such as the police station building near the town square and the school building on the eastern fringe of the town, may look as though they may be rehabilitated by repair. However, to the experienced engineer who analyzes the structural injury rather than external appearance, these buildings should be condemned and demolished. The same standard should be applied in appraising other buildings for demolition or rehabilitation.

VI. Reconstruction of Barce

Necessary decisions must be made by the Government with respect to the site for rebuilding the town of Barce and the allocation of funds for reconstruction in order to proceed with the architectural and engineering designs and plans.

Once the basic decisions are made, it may be advisable from the point of view of gaining time to engage the professional services of a competent and responsible Consultant firm or group to develop the designs, specifications, drawings, and documents required for legislation, awarding of contracts, and general direction of the reconstruction operations. Advisers may also be retained by the Government to advise on the reconstruction programme until satisfactory implementation is accomplished.

It is hoped that earthquake resistant buildings embodying the structural features recommended in the report will be built in the new town of Barce.

VII. Conclusion and Recommendations

A. Barce Earthquake and its Effects on Structures

1. Barce earthquake was a moderate and not a severe earthquake. Earthquakes of this magnitude should not cause major damage to man-made structures if proper precautions are taken against them.

2. Damage to buildings of unreinforced rubble stone embedded in mud and those of stones or blocks jointed in lime-cement or cement mortars suffered severe to total damage. This phenomenon is quite common and should be remembered.

3. One storey dwellings of unreinforced hollow concrete blocks suffered moderate damage. It is possible to make this type of construction earthquake resistant by proper reinforcement as recommended in Section IV.

4. Buildings with structural frames of reinforced concrete with filler walls did not fail.

5. Well designed and carefully constructed buildings and elevated water tanks of reinforced concrete and steel construction were not structurally damaged.

B. Earthquake Resistant Regulations:

6. It is recommended that buildings and structures in the Barce Plain and other seismic zones of Libya be designed and constructed to possess adequate earthquake resistance.

7. Earthquake resistant regulations that are deemed suitable for the Barce region have been prepared which are recommended for adoption.

C. Structural Standards and Recommended Practice

8. In the light of recent experiences from the Barce earthquake, rubble stone embedded in mud and unreinforced stone or blocks jointed in cement mortar should not be used in seismic areas.

9. Reinforced hollow concrete block construction is recommended for one storey houses.

10. The use of reinforced concrete space frames for buildings that are more than one storey in height is recommended.

11. Reinforced concrete and or steel construction is recommended for important and heavy buildings and structures, such as silos, warehouses and elevated water tanks.

D. Relocation of Barce

12. A new site near to but at higher elevation than the present town site is recommended from the point of view of less earthquake hazard.

13. A new town of Barce on a new site constructed according to a model, up-to-date town plan seems preferable to rebuilding on the present site. A modern town may contribute to further regional development and also promote tourism.

14. Due to presence of damaged buildings in the present town, implementation of reconstruction on the old site may present practical and legal difficulties and delay reconstruction.

15. From the earthquake engineering point of view, it would be possible technically to rebuild on the present site. However, the dangers from any future earthquake would be greater than on a better site and construction will be more expensive.

E. Reconstruction of Barce

16. Government decisions on the site for rebuilding Barce and budgetary allocation of funds for reconstruction are necessary to prepare and implement Barce reconstruction.

17. Effort be made to form a strong technical engineering organization in the Government to provide engineering services on public programs. It is recommended that engineers in different Ministries participate in the Barce reconstruction project as much as feasible.

18. For quick and efficient execution, it is recommended that the Government engage a Consultant firm of group, of technical competence and reliability, to prepare and execute the Barce reconstruction programme. The Government may also retain the services of Advisers to give assistance and advice on reconstruction.

19. Dispensing of relief and assistance to earthquake victims, based on surveys of bodily and property damages, should be carried out promptly and plans for their health and welfare during the winter season be prepared well in advance.

20. Action be taken by the Government on the Memorandum to the Council of Ministers on the subject of Barce Reconstruction from the Minister of Planning and Development, dated 26 May 1963.

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Photo 1 The heap of rubble stones in the heart of the popular housing area. The remains of the fallen roof consisting of wooden rafters seen in the center. Among the ruins, a building with reinforced concrete columns and girders remains standing though damaged.

Photo 2 An example of damage to a house of rubble stones embedded in terra rossa. Note the roof construction consisting of stones and mud over wooden rafters.

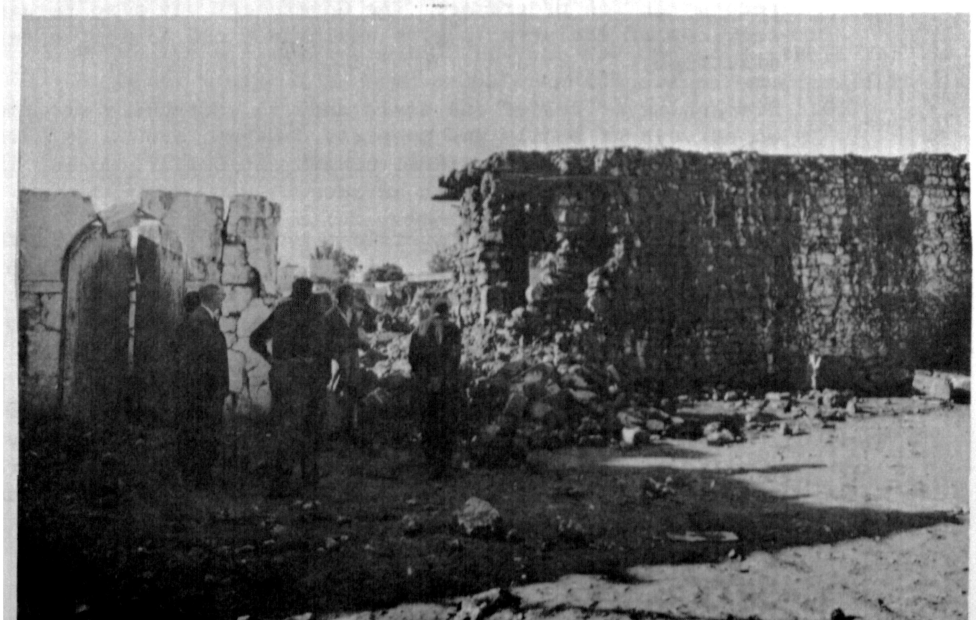


Photo 3 An example of damage to a rubble stone and mud house located at a corner. The curved portion of the wall is standing precariously.

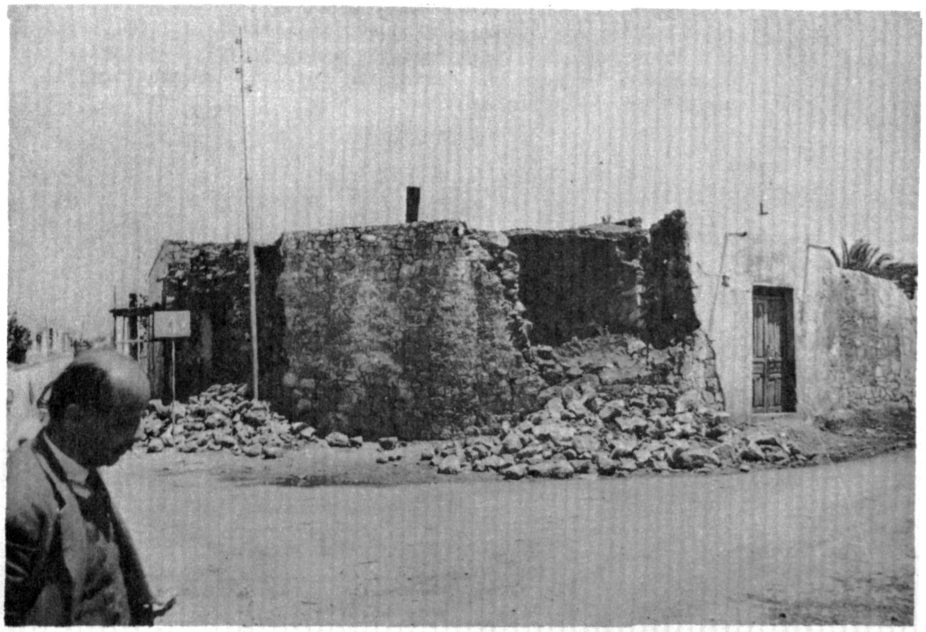


Photo 4 An example of collapse of rubble stone walls which enclosed the inside frame consisting of discarded metallic rolling stock. To the right is a building of stone block under construction which is provided with reinforced concrete columns that was saved from collapse.

Photo 5 Severe damage to fort-like farm houses in the area north of Maddalena (some 12 km northeast of the town of Barce), which were built by the Italians for agricultural colonists. The walls of rubble stone laid in lime-cement mortar were more bullet proof than earthquake resistant. Heavy weight is a distinct disadvantage from the stand point of seismic resistance because the earthquake force is proportional to the weight of the building.

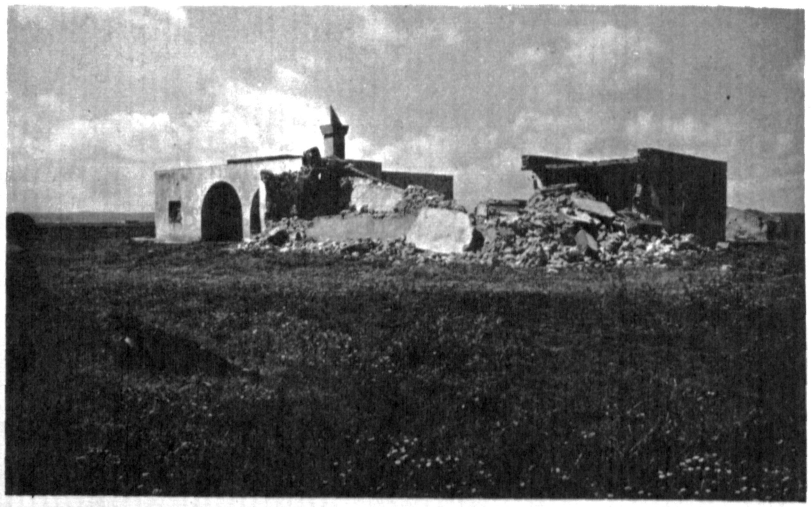
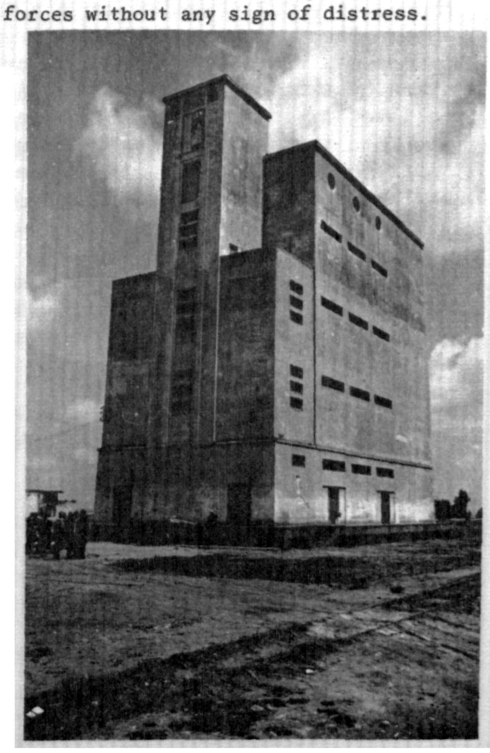


Photo 6 The damge to a wall of hollow concrete block construction of a typical low-cost dwelling house. These housing units are located on the western fringe of the town and they suffered only moderate damage from the recent earthquake. By making certain structural changes in the design and construction, houses of this type of construction may be made adequately earthquake resistant. The low height is an advantage in reducing the weight and seismic stresses. Note the trees in this neighborhood and the happy people. The new site for the reconstructed town of Barce should be located, to save these trees as much as possible.

Photo 7 Elevated water tank of reinforced concrete construction near the railway station. No damage of any kind. This is an example of a structure well designed and well constructed following good engineering procedures.

Photo 8 The five-storey silo building of reinforced concrete construction. Only walls that used stone blocks were damaged. The structural members and reinforced concrete walls withstood the earthquake forces without any sign of distress.



RELOCATION AND RECONSTRUCTION OF THE TOWN OF BARCE, CYRENAICA, LIBYA, DAMAGED BY THE EARTHQUAKE OF 21 FEBRUARY, 1963.

D I S C U S S I O N

BY J.K. MINAMI

Professor Ambraseys made comments on focal depth determination and stated that in many instances, the focal depth of shallow earthquakes could be determined by careful observations of earthquake damage (intensity) to buildings and other structures. Mr. Garden expressed doubt that accurate focal depths of shallow earthquakes could be determined in all cases due to incomplete understanding of the mechanism of crust failure in an earthquake. Dr. Kawasumi agreed with Prof. Ambraseys and showed some examples of focal depth determination in Japan. Dr. Carder also agreed in general with the reservation that care must be taken of the geology of the region because, if the focus is very shallow, the energy may be confined in large part to a wave guide and be carried long distances. In reference to the focal depths given on page 1 of the paper, these are fairly arbitrary. In fact, they may be 33km $\pm$ 33km - or perhaps more accurately $\pm$ 25 km. He believed that the focal depth for the Barce earthquake was much less than 33 km. The magnitude scale is also rough - perhaps by a factor of $\pm$ 0.5 depending on the data used and methods of interpreting them. The Coast and Geodetic Survey epicenters used in this and earlier papers may be in error by 20 km or more - again depending on the distribution of seismograph stations. As to the Barce epicenter, however, he believed it to be fairly accurate as considerable attention has been given to this earthquake. The Author thanked Dr. Carder and others for their comments, and expressed his opinion that his observations of this earthquake in and around Barce substantiated Dr. Carder's comments.

RECENT STRONG MOTION EARTHQUAKES AND RESULTING DAMAGE

BY J. DESPEYROUX *

DISCUSSION

A parallel between some recent earthquake suggestions about the intensity scale.

There is a point which seems worth emphasising after the earthquakes we experienced in the last few years.

At first, there is a rather close analogy between some Mediterranean earthquakes, like Agadir 1960, Skopje 1963, and several minor shocks in the same area: they all are shocks of low magnitude and their destructiveness is due to the fact that the cities they struck were located near the epicentre. In these earthquakes, if we look at modern well built constructions, the low rigid structures suffered heavy damage, and, comparitively, the taller buildings did not suffer so much. It is an indication of a large proportion of high frequency components in the ground motion and/or a short duration of the shock, this duration being too short for the low frequency components to excite large responses in tall buildings.

On the other hand, if we look at such earthquakes as Mexico 1957 and Alaska 1964, it is exactly the contrary: they were shocks of large magnitude, which struck cities situated at a long distance from the epicentre, the seismic wave having to cross wide areas of soft soils before arriving at the town. The lower buildings, as long as they did not sink in a crevace or a landslide, did not suffer heavy damage, while the tall structures were severely affected. These effects seem to indicate that the high frequencies components had been dampened out in a significant manner while crossing the soft soil areas, and that, the shock being of a long duration, the long period components had time enough to excite high responses in tall buildings.

Unfortunately, we have no strong-motion record of the Alaskan earthquake. Nevertheless, I think that, after this quake, we have to prepare our minds to a revision of the shape of the standard response spectrum.

The intensity scales also, even the revised intensity scale proposed to UNESCO by Karnik and others, seem to need some improvements, since in the case of the Anchorage earthquake it is possible to give different estimations of the intensity, according to the type of structures considered. I think that a more realistic description of the ground motion by means of the notion of intensity could be obtained by dividing the structures into

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several classes, according to their period (by instance short periods : $T < 0.4$ sec. ; medium periods : $0.4 < T < 0.8$ sec. ; long periods : $T > 0.8$ sec.) and giving the intensity as a set of three numbers corresponding to the three classes of structures.