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STRONG MOTION RECORDS IN THE SOURCE AREA OF THE HYOGOKEN-NAMBU EARTHQUAKE, JANUARY 17, 1995, JAPAN

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ABSTRACT

Strong motion data were recorded in the vicinity of the source area during the Hyogoken-nambu earthquake, 05:46 January 17, 1995. Observation sites have been established by the Committee on Earthquake Observation and Research in the Kansai Area (CEORKA). Two of them are deployed in Kobe which fault rupture reached during the mainshock and which are adjacent to a heavily damaged area. The horizontal maximum velocity recorded at a rock site, Kobe University, was 55 cm/s. Strong motion data also was recorded at the Japan Meteorological Agency (JMA) site in the central area of Kobe (horizontal max. 818 cm/s^2). The Kobe City Office recorded horizontal max. 341 cm/s^2 at a reclaimed island. In this paper, seismograms in the source area recorded by CEORKA are shown and compared with the data recorded by the JMA and Kobe City Office.

1. INTRODUCTION

The Committee on Earthquake Observation and Research in the Kansai Area (CEORKA) was established in December, 1991 to obtain broad frequency band and wide dynamic range strong motion data in the Kansai area, a region that includes three mega cities: Kyoto, Osaka, and Kobe [1]. The initial members of CEORKA are listed in Table 1.

CEORKA set up 11 observation sites in and around the Osaka sedimentary basin in April, 1994 [2]. The main aim of the observations was to obtain basic information on the effects of surface geology, in particular surface wave propagation excited by the Osaka sedimentary basin. We had a plan to use the information for reduction of earthquake damage.

2. RECORDING SYSTEM

The seismograph installed is the servo velocity type, and the data recording system is a 16 bits digital IC card recorder . The specifications of the recording system are shown in Table 2. Wide dynamic range type systems are installed only at three sites: Kobe University (rock), Chihaya (rock), and Yae (sediments). Their locations are shown in Fig. 1.

The data recording system has a function that calls a host computer through a modem phone after it detects an event. After catching the call from one of the observation sites, the host computer (Engineering Work Station) in the center station (Geo-Research Institute, Osaka) automatically starts operations to obtain the maximum value for all the sites and downloads data. When

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Table 1 The initial members of CEORKA. The left column lists individual research members and the right column lists group or company members. The chairman and chief of the subcommittee respectively are marked '*' and '**'. Financial supporters are indicated by solid circles. The secretariat is shown by '@'.

K. Toki *	JMA, Osaka
K. Irikura **	Shiga Prefecture
Y. Yoko-o	Kyoto Prefecture
S. Horiuchi	Osaka Prefecture
S. Yoshikawa	Hyogo Prefecture
K. Akai	Wakayama Prefecture
Y. Yamada	Kyoto City
H. Iemura	Osaka City
M. Kohno	Kobe City
T. Hasegawa	●The Kansai Electric Power Co., Inc.
Y. Umeda	●Osaka Gas Co., Ltd.
S. Sawada	●Hanshin Expressway Public Co.
K. Kamae	West Japan Railway Company
Y. Inoue	●Nikken Sekkei Co., Ltd.
A. Terashima	●Hanshin Consultants Co., Ltd.
S. Takada	●Obayashi Co.
K. Kusakabe	●Kajima Co.
S. Sakaguchi	●Kumagai Gumi Co., Ltd.
M. Nakamura	●Konoike Construction Co., Ltd.
Y. Takeuchi	●Sato Kogyo Co., Ltd.
M. Horike	●Shimizu Construction Co., Ltd.
K. Fukumoto	●Matsumura-Gumi Co.
K. Nakagawa	●Kansai Institute of Information Systems
Y. Kitagawa	●Geo-Research Institute, Osaka @

Table 2 Basic specifications of the recording system used by CEORCA.

		Standard	Wide Range
Seismometer	Frequency Range	40sec.~70Hz	
	Full Scale (10 Volt.)	Low Gain 40cm/s High Gain 1cm/s	Low Gain 100cm/s High Gain 5cm/s
		Acc. 1,000cm/s2	
Recorder	Channel	3	6
	Sampling	100Hz is used	
	Pre-Trigger	30sec. is used	
	Trigger Type	Dynamic Level, Logical	
	Interface	RS-232C(Up to 38,400bps.)	
	Clock	Radio Wave Correctted	

receiving information from the sites, the host computer broadcast the informations to radio pagers [2].

3. OBSERVED RECORDS

Figure 2 shows the observed uncorrected velocity waveforms at all the sites of CEORKA. All traces have a common time and are normalized by a common amplitude scale. The nearest site to the faulting zone is Kobe University, near a rock outcrop, and is considered to be located just above the source area. At the site, a maximum horizontal velocity of 55.1 cm/s was recorded in the NS direction. Whole components at the Kobe site and horizontal components at the Amagasaki site were clipped at 40 cm/s. In the areas surrounding these sites, however, damage was light. At

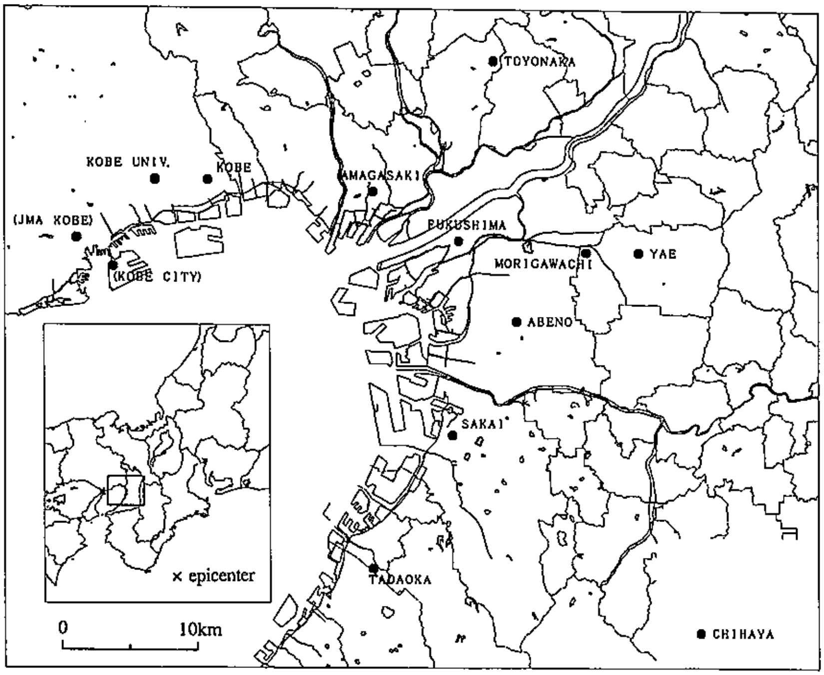

Fig. 1 Locations of the observation sites deployed by CEORKA. The epicenter established by the JMA is plotted in the inset map.

the Toyonaka site, the digital data unfortunately was lost because of a malfunction in the center station. The analogue record on paper is available. Site conditions are reported in Table 3.

Acceleration differentiated from the velocity record and displacement integrated at the Kobe University site are shown in Fig. 3. A high-pass filter (cut-off 0.1Hz) is adopted before making frequency domain operations. The maximum horizontal acceleration is 305 cm/s^2 in the EW component. Peak vertical acceleration is calculated as 446 cm/s^2, with only an impulsive wavelet. We suspect that the peak acceleration in the UD component is somehow affected by the inclination of the sensor. It is clear that light offsets remain just after the mainshock in the horizontal components. From the offset amplitude, the upward inclinations of the sensors are estimated as 0.021 and 0.024 degrees in the south and west directions respectively. We must examine the sensor characteristics in detail to obtain the corrected UD component record. We expect that the peak acceleration of the UD component will become smaller after the examination. As for displacement, the frequency domain high-pass filter seems to have a strong effect (especially in the UD component), because the record is suspected to be disturbed by a step-like zero-offset. Pseudo velocity response spectra (h=0, 0.02, 0.05, 0.1) also are shown in the figure. Their peaks tend to be at about 1 second. Peak acceleration responses of the horizontal components are more than 2G (G: acceleration of gravity), notwithstanding being recorded at rock site.

In Fig. 4, the acceleration waveform at the JMA Kobe site is shown with integrated velocity and displacement. The recording system is considered accurate enough at periods from 0.1 to 10 seconds (Table 4). The site is located in the vicinity of a heavily damaged area , downtown Kobe, about 2 km distant; but damage in the close vicinity of the JMA Kobe site was not particularly severe. The peak ground acceleration is 818 cm/s^2 in NS component. The maximum recorded vertical acceleration is 332 cm/s^2. The pseudo velocity response is shown on the right in Fig.

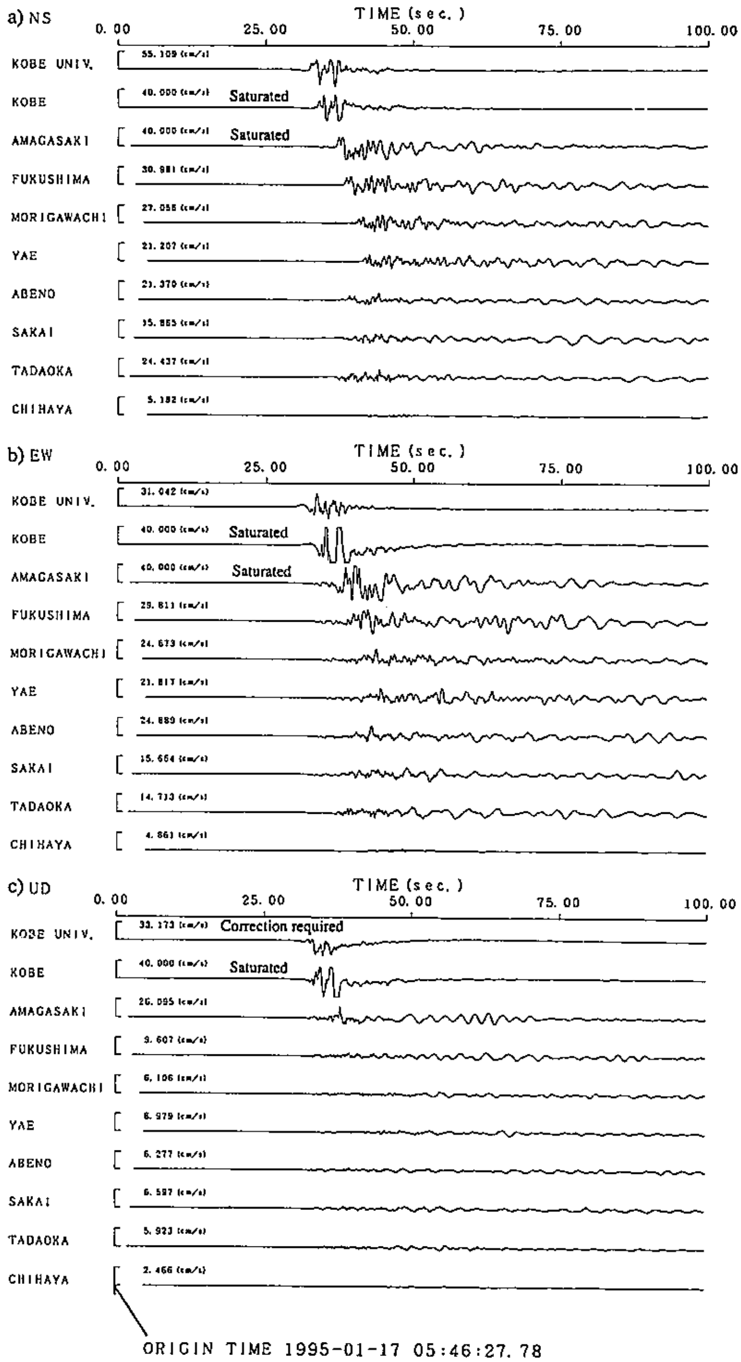

Fig. 2 Uncorrected velocity waveforms recorded by CEORKA, a) NS, b) EW, c) UD components.

4. The peak frequencies of the spectra seem to be slightly shorter than those of the Kobe University site.

Table 3 Site conditions for all the sites of CEORCA, JMA Kobe, and the Kobe City Office.

Site	Latitude	Longitude	Altitude	Soil Conditions
Kobe-Univ.	N34.725	E135.240	110m	Mesozoic granite
Kobe	N34.725	E135.281	25m	Late Pleistocene fan deposits
Amagasaki	N34.718	E135.408	0m	Thick Holocene deposits
Fukushima	N34.687	E135.474	0m	Thick Holocene deposits
Morigawachi	N34.680	E135.572	1m	Thick Holocene deposits
Yae	N34.680	E135.612	3m	Thick Holocene deposits
Toyonaka	N34.801	E135.501	55m	Pliocene deposits
Sakai	N34.564	E135.462	2m	Thin Holocene deposits
Tadaoka	N34.480	E135.408	12m	Thin Holocene deposits
Chihaya	N34.439	E135.659	280m	Mesozoic granite
Abeno	N34.636	E135.519	12m	Late Pleistocene deposits
(JMA Kobe)	N34.688	E135.180	59m	Middle Pleistocene deposits
(Kobe City)	N34.670	E135.208	4m	Reclaimed land

4. DISCUSSION

We compared the seismograms at the Kobe University and JMA Kobe sites. From the velocity waveforms in the NS component, clear double shocks could be detected at the Kobe University site. The interval between the two shock is about 2.5 seconds and the second shock has larger amplitude than the primary one. The JMA Kobe site shows the same features, but the second event 2.5 seconds after the first event has smaller amplitude at the JMA Kobe site. This suggests that the second large event was occurred closer to the Kobe University site than to the JMA Kobe site.

The Fourier spectral amplitude ratio of the JMA Kobe to the Kobe University records is shown in Fig. 5. It was calculated after vectorial summation of two horizontal components in the frequency domain. The JMA Kobe record is integrated into the velocity before calculating the spectral ratio. The Hanning smooth window is applied twice. Because both sites are located above the source area, no distance correction was made. The ground motion at JMA Kobe is amplified two to five times that at Kobe University in period range between 0.2 and 1.0 second. As mentioned before, in the vicinity of the JMA Kobe and the Kobe University sites, there was no heavy damage. We speculate that much larger ground motion struck the severely damaged areas than struck the observation sites.

Figure 6 shows the data recorded on a reclaimed island by the Kobe City Office. The basic specifications of the recording system are shown in Table 4. Although the reclaimed island was damaged by liquefaction, damage to buildings was light. The maximum horizontal acceleration is 341 cm/s^2 in the NS direction. It is smaller than that for JMA Kobe, nevertheless it is set on soft sediments. The periods of oscillations become longer and the amplitudes of the oscillations become smaller in the horizontal components in the traces after about 13 seconds, whereas the data at the Kobe University and JMA Kobe sites do not have these features. The low acceleration at the reclaimed land may be due to the non-linear effect of soil. As for the UD component, the maximum acceleration is 556 cm/s^2 and a high frequency is dominant. The peak appears just after the shear wave arrival. We must continue the study of the mechanisms that caused the large vertical acceleration.

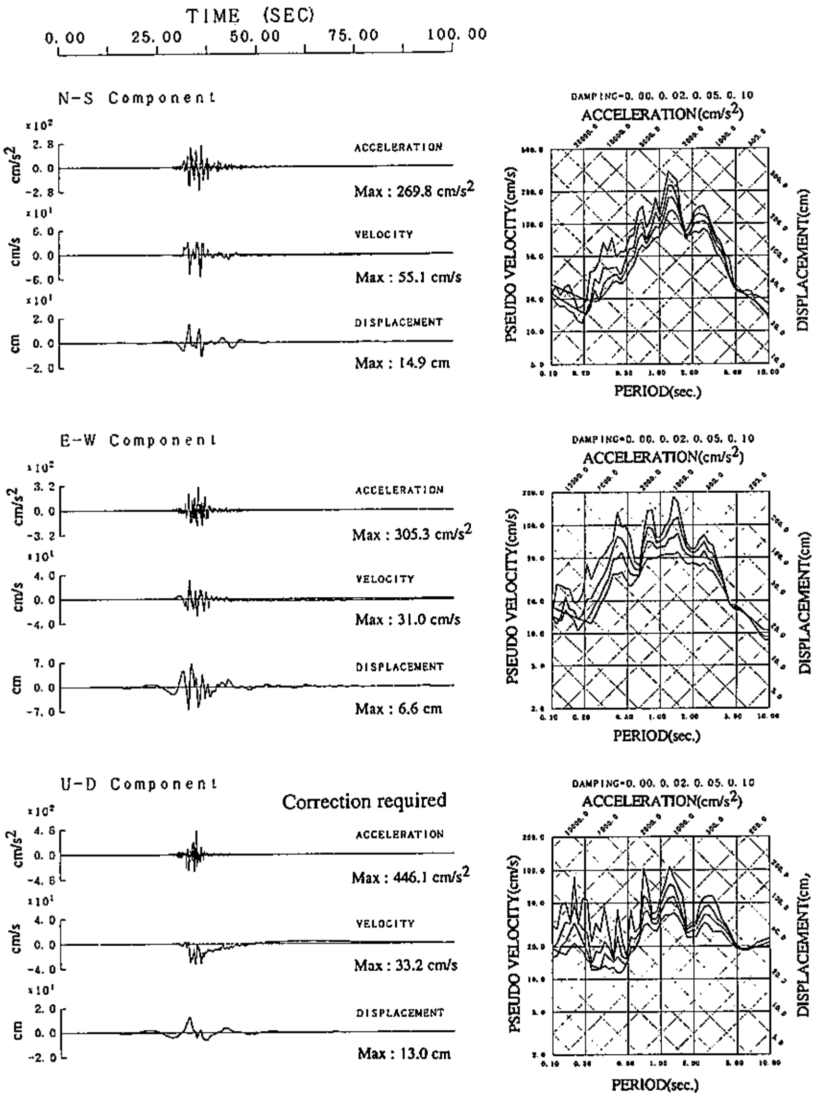

Fig. 3 Observed velocity waveform at the Kobe University site. Differentiated acceleration, integrated displacement, and pseudo velocity response spectra(h=0, 0.02, 0.05, 0.1) are shown. Care must be taken in using the UD component as it is suspected to have an instability. The traces for the UD component are tentative plots.

5. CONCLUSION

CEORKA obtained strong motion records in the vicinity of the source area of the 1995 Hyogoken-nambu earthquake. A brief summary of the data shows:

1) Observed peak horizontal accelerations are 305 cm/s^2 at a rock site (Kobe University), 818 cm/s^2 at a late Pleistocene site (JMA Kobe) and 341 cm/s^2 at a reclaimed island (Kobe City),
2) Several multiple events were detected from near source seismograms,
3) A comparison of the Fourier amplitude ratio of the JMA Kobe record with that of the

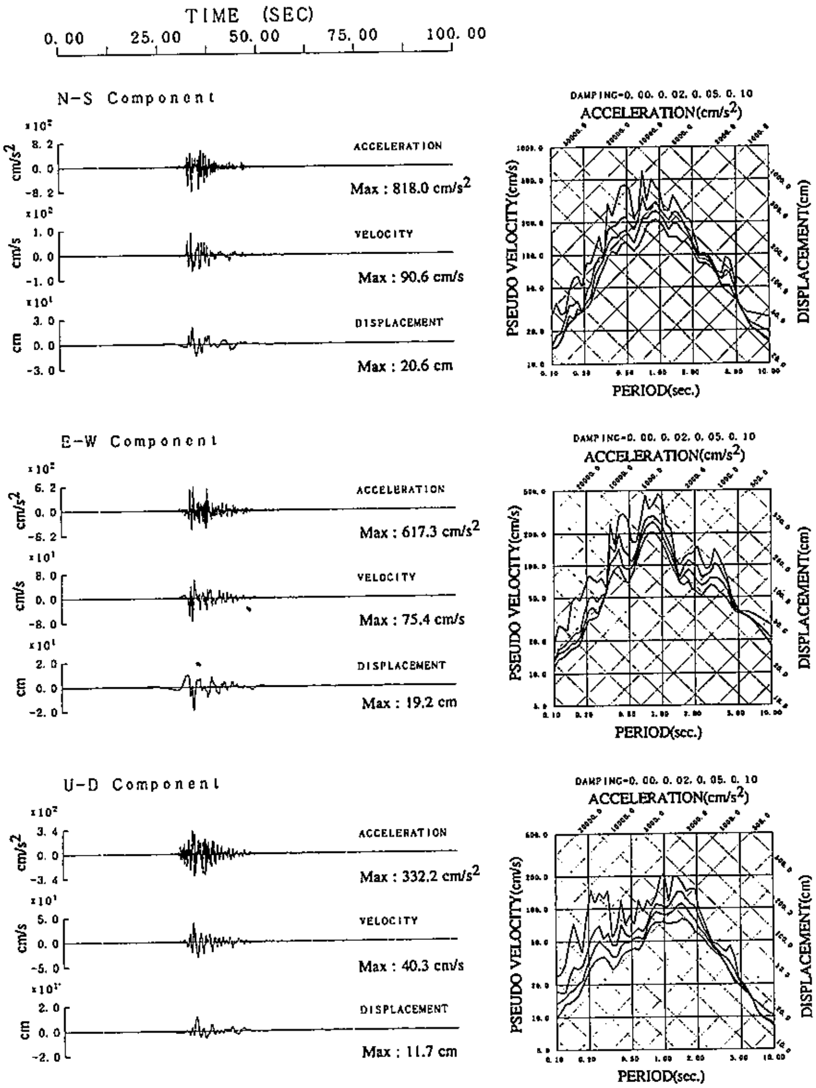

Fig. 4 Observed acceleration waveform at the JMA Kobe site. Velocity and displacement integrated from the original records and the pseudo velocity response spectra are shown as in Fig. 3.

Kobe University site, shows ground motion at the JMA Kobe site is amplified two to five times that at Kobe University in the period range shorter than 1.0 second,

4) The data recorded at a reclaimed island seem to be affected by the non-linear effects of soil.

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Table 4 Basic specifications of the recording systems used by the JMA Kobe and the Kobe City Office.

		Sites	
		JMA Kobe	Kobe City
Seismometer	Type	Servo-Acc.	Servo-Acc.
	Frequency Range	DC ~ 400Hz	0.1 ~ 30Hz
	Full Scale	980 cm/s2	1000 cm/s2
Recorder	Type	16 bits digital	16 bits digital
	Channel	3	12
	Sampling	50Hz	100Hz is used
	Pre-Trigger	—	10 sec. is used
	Band-Pass Filter	0.001 ~ 10Hz	~30Hz
	Clock	Radio Wave Correctted	Radio Wave Correctted

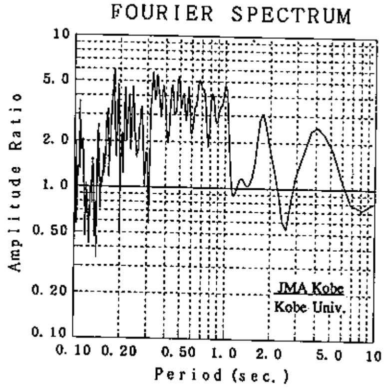

Fig. 5 Fourier spectral ratio of the JMA Kobe record to the Kobe University record.

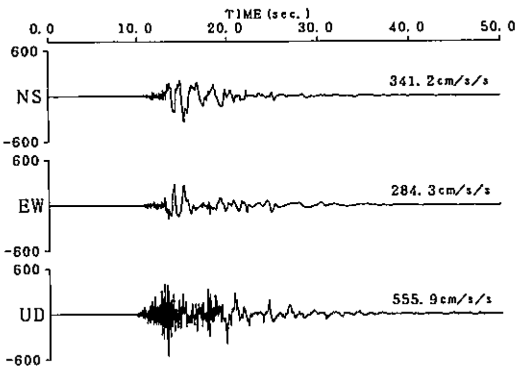

Fig. 6 Observed accelerogram obtained by the Kobe City Office on the surface of a reclaimed island.

and Prof. Takada made great efforts to collect the records at the Kobe University and Kobe sites just after the mainshock when those sites were isolated because of the catastrophic damages to Kobe. Dr. T. Iwata, and Mr. K. Hatayama shared their time and expertise in establishing the observation sites. Prof. Nishi and Mr. Ichinari kindly helped us to construct the Kobe University site. Mr. Yokoi and the staff of Tokyo Sokushin Co., Ltd. assisted us in carrying out the observations and examining the data. The JMA published the observed digital record very quickly. Kobe City provided the observed data to CEORCA. Mr. Y. T. Iwasaki promoted CEORKA. We express our gratitude to all the participants.

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