A Construction Trail of Community Roads at Low Cost by Resident's Participation in Gher Area in Ulaanbaatar Site of Mongolia

Z. Binderiya, R. Bollormaa, J. Davaasuren, P. Otgonbayar, M. Tsas-Orgilmaa, & S. Khasnavch
Mongolian University of Science and Technology, Ulaanbaatar, Mongolia

T. Momoi
Ashikaga Institute of Technology, Ashikaga, Tochigi, Japan
Infrastructure Development Institute, Tokyo, Japan

H. Fujishima
Ashikaga Institute of Technology, Ashikaga, Tochigi, Japan

ABSTRCT: The present paper is concerned with road projects on community roads, constructed in Gher areas of Ulaanbaatar, Mongolia. The Gher is our nation's traditional houses, in which families with low income are not well off. The purpose of the project is to build the community roads at low cost and to permit Gher residents to participate in the works as well as preparing a manual to build the community road. From 1999 down to this day, the project teams conducted constructions of test roads at four places, follow up investigations using portable Falling Weight Deflectmeter and Dynamic Cone Penetrometer, and indoor tests such as freeze-thaw and wet-dry. We may conclude that road structures, consisted of bituminous surface treatments and cement stabilized base courses, are suitable technically and economically for pavements of the community road in extremely cold and dry areas of Mongolia. This paper explains the detailed story of the studies and a few problems encountered on applying the compiled manual into practical use.

KEYWORD: Low cost road, cement stabilization, bituminous surface treatment, FWD, DCP.

1 INTRODUCTION

Designation of two routes in Mongolia for Asian Highways was agreed at Expert Group Meetings on development of highway networks in Asian Republics held in 1995. Mongolian governments commenced constructions of these main routes and intended to build domestic roads connecting to these routes. On the other hand, Mongolia is fortunately rich in natural resources of limestone, so that the Governments tried to develop Portland cement making industries. The Road Department drafted a plan on applications of cement stabilizations for constructing courses and wearing courses of the domestic roads. However, with landlocked location and relatively high average elevation, Mongolia has continental types of climate with mild to moderate summers and severe winters.

Research projects on cement stabilization in Mongolia were collaborated by Mongolian University of Science and Technology (MUST) and Ashikaga Institute of Technology Japan

(AIT) from 1999 to 2002. Field and indoor tests were carried to investigate durability of cement stabilized base course (CSTB) and cement stabilized wearing courses (CSTW) against the extremely cold and dry weather in Mongolia. It was concluded that CSTB is of much practical use for the base course of the domestic roads, although CSTW is unsuitable for the wearing course of the domestic roads.

From December 2004 to September 2006, the Japan International Cooperation Agency (JICA) project of “Development of life environment in the Baganuur Gher district (Development of community road)” was conducted in collaboration with the Association of Mongolian Road Engineers and the Infrastructure Development Institute Japan. The Gher is our nation’s traditional houses, in which families with low income are not well off. The Gher areas are in situation of poor infrastructure networks such as local road, water and sewage. Purposes of the project were firstly to build community roads at low cost in order to improve a living environment in the Gher area, secondary to allow Gehr residents participate in constructing roads in order to create and increase job opportunities for them, and lastly to prepare a manual to enable to build the community road along the above lines.

In 2004 the community road was constructed to contrive working procedures applicable to participation of Gher residents in the road constructing works. The project team selected the frost-free selected subgrade (SSub) according to Mongolian Highway Standard, and CSTB as the base course with reference to the results of the preceding cooperative study, as well as labor-intensive bituminous surface treatments (BST) as the surface course in accordance with the purpose of the project. Organizing the data obtained by the process of building the community road, the manual for community road was prepared in 2006.

1n 2007, three years after completion of the construction, MUST-AIT study group executed follow up investigations on the community roads, in which the old rough-and-ready and portable instruments were used, such as MRR profilometer, Dynamic cone penetrometer, Benkelman beam and portable or lightweight Falling Weight Deflectmeter.

From the constructions of test road and the follow up investigations described above, it was concluded that the pavement structures, consisted of SSub, CSTB and BST, were suitable technically and economically for pavements of the community road in the Gher districts.

2 CEMENT STABILIZAITON IN MONGOLIA

To investigate durability of CSTB and CSTW against the severe weather in Mongolia, the study group constructed test roads at Nogoon Dov in August 1999, and carried out follow up investigations and indoor tests including the freeze-thaw, the wet-dry and the raveling tests from September 1999 to August 2002.

2.1 Test roads at Nogoon Dov

The test road, built at Nogoon Dov of 90 km south away from Ulaanbaatar, was of 6m in width and 500m in length was (Figure 1) (Binderiya, 1999, Momoi, 2009). In this area, it was about 50 in average daily heavy cargo's passage in both directions. SSub were composed of gravelly soils with not exceeding 10% fines passing 0.075mm. In CSTB, pit gravels were mixed in place with cements by motor graders. CSTB of each section in the test road had various thickness and various amounts of cement contents.

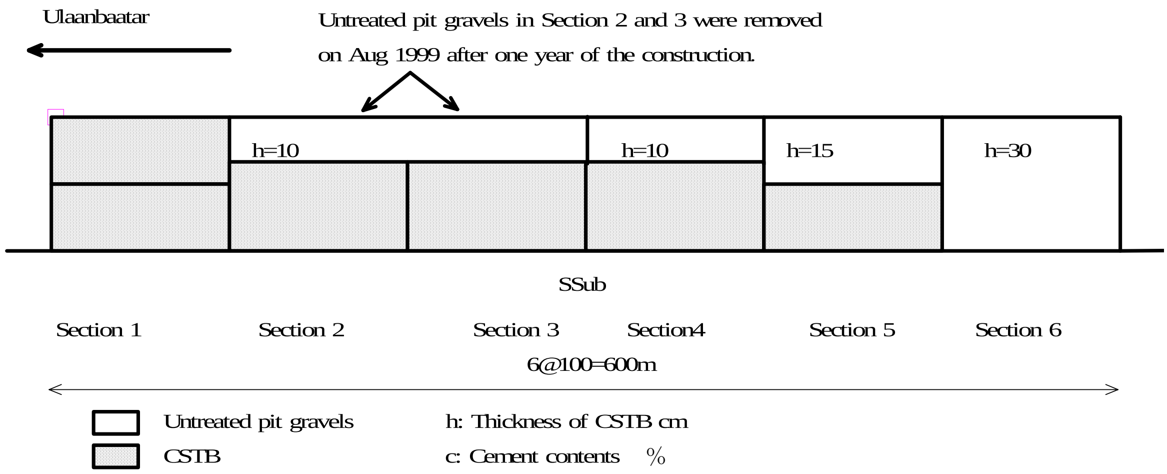

Figure 1: Plan view and road structures in Nogoon Dov Test Road

Follow-up investigations were started immediately after the construction work was finished. Those were conducted in a frequency of once a month for three years, although those were set to work at an unspecified time in the daytime.

To investigate the effect of the severe climate in Mongolia on thermal penetration into the test road, soil temperatures and soil moistures were measured with thermocouples and devices of TRIME-T3, respectively (IMKO, 1997). According to another indoor test, it was obvious that with a soil temperature below freezing points, the moisture readings of the TRIME-T3 were deficient in reliability (Shoji, 2004). Those were disregarded. In Figure 2, both the temperatures and the moisture in the shallow portion of the depth of about 2.5m under the surface showed violent seasonal variations, and were relatively high in its values during May-Sep. In the regions deeper than about 2.5 m, both values were less variable thorough all years around.

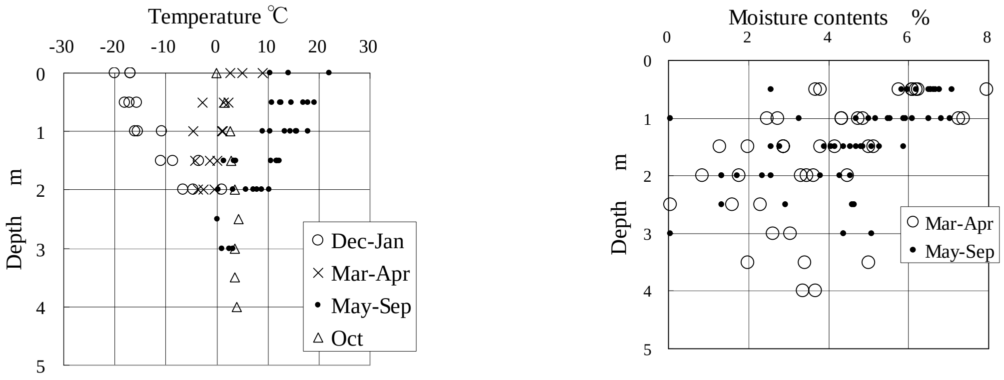

Figure 2: Temperature and moisture distribution in direction of depth.

An irregularity on the surface in a longitudinal direction was surveyed by means of the MRR Profilometer and evaluated by index of International Roughness Index (IRI) (Cundill, 1996). The IRI increases stepwise year by year as shown in Figure 3. Considerable increments of IRI were observed every autumn (Sep-Oct). At 2.9 years after commencement of service, the values reached to 8 to 12 m/km, which indicated the surface had attained to the state of ‘Very rough paved road’ according to standard evaluation of IRI. Field tests on the rutting depth and the crack ratio also showed that the life of CSTB was between 2 and 3 years. It was concluded from the above view that CSTB was resistless to the direct scratching shears due to wheel traffic.

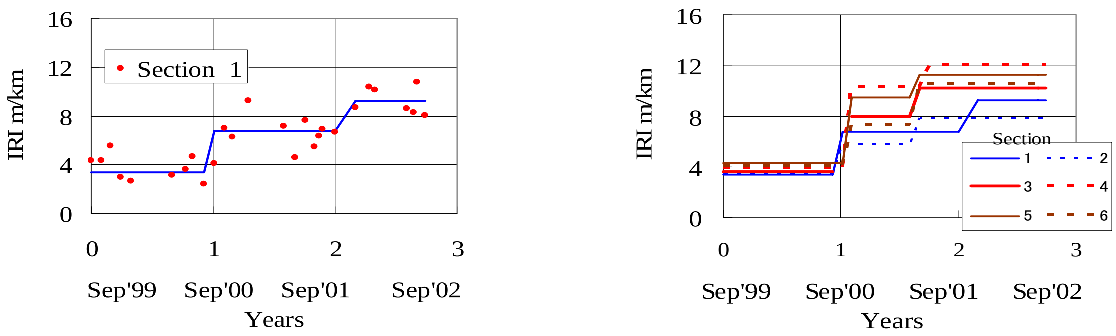

Figure 3: Performance chart on change in IRI

In Deflection measurements with Benkelman beam, the weight of loading truck was adjusted to the dual wheel load of 35kN. In Figure 4, the values of deflection were almost zero during from October to March of the following year. Pronounced deflections were observed for a period from May to September, the amounts of which were held approximately constant and unchanged within each year. The amounts increased stepwise with passages of the year. Nevertheless, it was obvious that the better the quality of stabilized layers (the higher the cement contents and the thicker the thickness), the lower the deflections in each year.

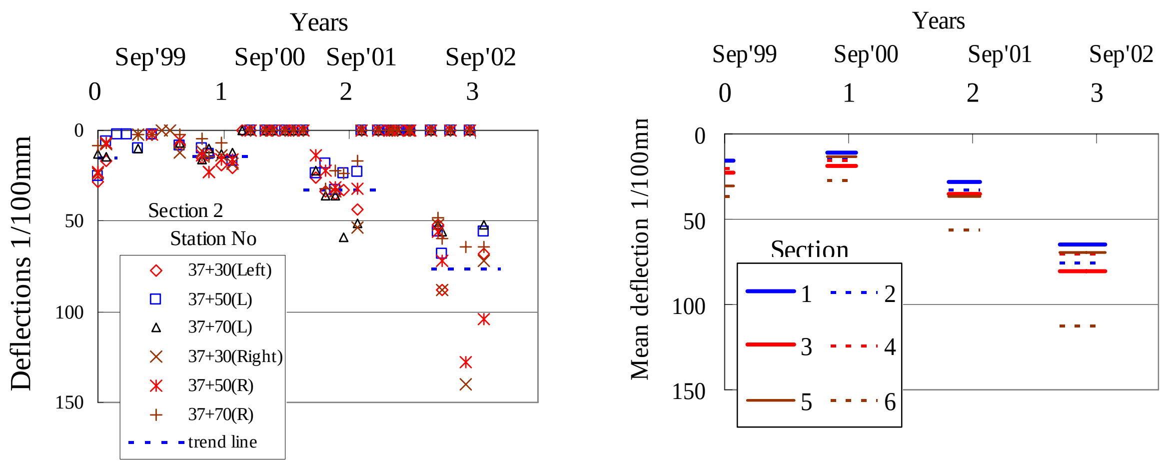

Figure 4: Annual variation of deflections measured by Benkelman beams

2.2 Indoor experiments on durability of cement stabilized materials

In indoor weathering tests such as freeze-thaw and wet-dry, durability of cement stabilized granular materials was evaluated with relative ratios of unconfined compressive strength after and before the weathering tests (Binderya, 2002). It was clear in the experimental regions that the relative strength ratio was not decreased even if the number of repetition of the freeze-thaw and the wet-dry increased.

In indoor raveling tests, the repeated raveling shear stress (created by both vertical and horizontal reciprocated forces) was applied to the surface of rectangular specimen made of the cement stabilized granular materials (Momoi, 2001). On the specimen without any surface dressing, the resistances against these stresses were in low level. However, when the surface of the specimen was dressed with bituminous emulsions, the resistance increased markedly.

From the field and indoor tests as above, it was concluded that cement stabilized granular materials was of much practical use in CSTB of domestic roads, even if it was mixed in place by motorgrader and exposed under the temperature and moisture conditions as shown in Figure 2. However, these materials were unsuitable for CSTW in the domestic road.

3 DEVELOPMENT OF COMMUNITY ROAD

In 2004, the project team constructed community roads together with about 200 man-days of the residents, and prepared a manual for community road. In 2007, three years after the completion of construction, follow up investigations were carried out to evaluate mechanical behaviors of pavement structures of the community road.

3.1 Community roads in Baganuur Gher district

The Community road of 8 m in width and 500m in length was built at Baganuur Gher district of 90 km east away from Ulaanbaatar (Figure 5) (Yano, 2007, Momoi, 2009). When designed, annual average daily traffic in both directions was assumed to be not more than 500. SSub was made of dirt heap granular materials, which were transported from overburden removal at the Baganuur surface-mined coal spoils and had 12 over in its CBR. The top 15 cm of SSub in Section 3 was stabilized with cements. The base course was composed of cement stabilized pit gravels or CSTB, water-bound Macadam (WBM) and untreated pit gravels in Section 1, 2 and 3, respectively.

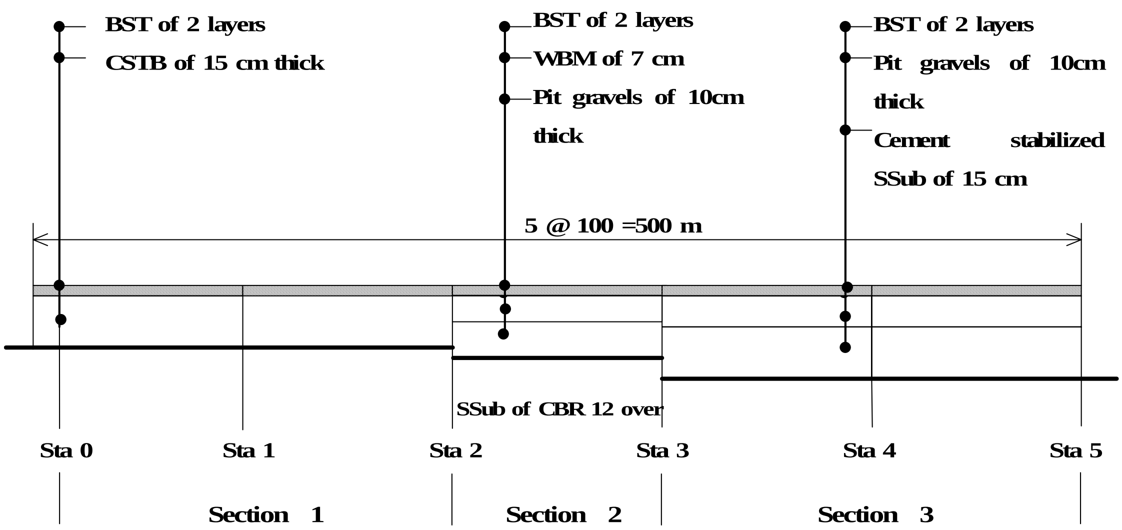

Figure 5: Pavement structures in Baganuur community roads

Construction procedures of the cement stabilizations in Baganuur were almost the same as that in Nogoon Dov. Required number of cement sacks was stationed at regular intervals over the roughly leveled raw materials (Figure 6). The sacks were opened and the cement powders were put uniformly by hand over the surface. The raw materials and the cements were mixed in place by motor graders. The mixtures were compacted by a pneumatic tire roller and a macadam roller. If the mixtures were exceedingly dry, the water was fed onto the surface by sprinkler trucks.

BST of double chippings was used for the surface course in whole sections of the community road (Figure 7). Binders (cut back bitumen) were distributed by engine sprayer onto the finished base course and then crushed stones were spread by hand labor only (Figure 6). After that, both were compacted with a pneumatic tire roller and a macadam roller. The process was repeated to provide double layers.

Figure 6: Labor intensive works in construction of CSTB and BST

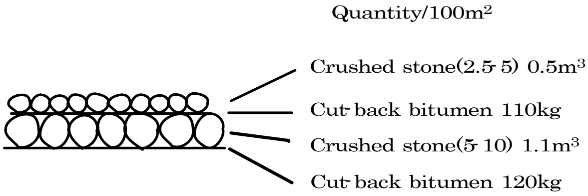

Figure 7: Working procedures in construction of BST

3.2 Follow up investigations

In 2005, one year after the completion of construction, the pavement in Section 2 was damaged and repaired. In 2007 three years after the construction, the follow up investigations were carried out. Although no evidence of damage to the community roads were found, linear cracks were observed in some places on the surface of whole Section. Values of IRI showed that the surfaces were kept at the level of ‘smooth paved road’ (Table 1).

Table 1: Roughness values IRI by Sections

Sections	Station	Roughness value, m/km	
		Right lane	Left lane
1	STA 0 – STA 1	1.84	1.92
	STA 1 – STA 2	1.97	1.96
2	STA 2 – STA 3	2.74	2.25
3	STA 3 – STA 4	2.26	1.92
	STA 4 – STA 5	1.99	2.07

Structural properties of the pavement structures were measured by means of Dynamic Cone Penetrometer (DCP) (TRL, 1990), in which an 8 kg hammer dropping through a height of 575mm and a 60° cone having a maximum diameter of 20mm. Figure 8 shows an example of results. The cone passes through stratums of varying penetration rate. It can be read off that each course corresponds to, in order from the top, BST, the pit gravel and the cement stabilized SSub, the thickness of which is about 2, 7 and 10 cm thick, respectively. The lowermost corresponds to untreated SSub. The thickness data, determined in much the same way as this, were summed as shown in Table 2. Rigidities of CSTB were too high for the DCP cone to pass through. Therefore the measurements could not be done in Section 1, so that the thickness of CSTB could not be confirmed.

In Table 2, the thickness of each course varied widely, besides, the average of the untreated pit gravels and the cement stabilized SSub was 7.4 and 11.1 cm, the both of which were below the proposed thickness of 10 and 15 cm. The penetration rates are converted into CBR values using DCP-CBR relationships. The value of CBR converted was about 57, 200 and 24 for the pit gravel, cement stabilized SSub and untreated SSub, respectively. It was understood that these values of CBR were reasonable empirically for each material.

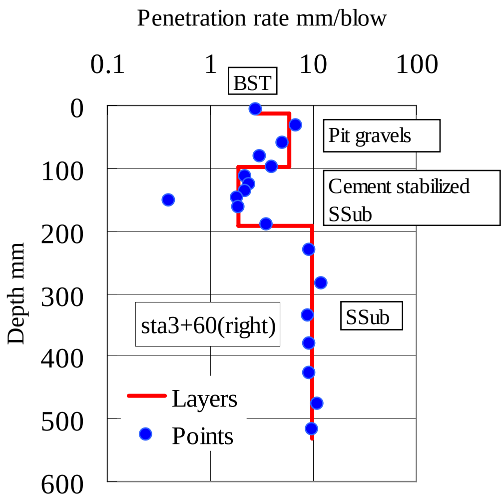

Figure 8 Test results on Dynamic Cone Penetrometer (DCP)

Elastic behaviors of the layer structures were evaluated by means of light weight Falling Weight Deflectmeter (LFWD) (JSCE, 2002). A mass of 15 kg slides down a shaft and falls on a rigid circular plate, diameter 100 mm, which rests on the pavement surface. With LFWD, the drop height was set at 500 mm, corresponding forces of around 8.5 kN. The force levels were checked by means of load cell. The deflections of the surface were measured by means of accelerometers, one in center of the loaded area and others at the fixed distance of 50, 100, 200 mm from the load. The surface temperature was on average about 32 degree C, which was measured with a contacting surface thermometer when LFWD tests were executed.

The back calculated deformation moduli varied widely as shown in the foregoing Table 2. It was considered that a cause for the wide variations was to include any inconsistencies. That is, in the process of the back calculation, the thickness of each course was assumed to be held constant over the whole area of the Section. However, it was obvious, from the DCP results as above, that the actual thickness of each course varied with the location in the Section

Nevertheless, rational conclusions were drawn as follows. When we put each course in increasing order the deformation modulus, the ranking become in the order of SSub, pit gravels, cement stabilized SSub and CSTB. Both the ranking and the average values of the moduli are reasonable empirically. We concluded from this that the possibility of applying LFWD method into the pavement structures analysis of the community road was increased, even if the structure includes BST and CSTB, which are made of thin and hard materials.

Table 2: Results on Dynamic Cone Penetrometer (DCP) and Lightweight Falling Weight Deflectmeter (LFWD)

	DCP							LFWD			
	Thickness cm			CBR converted %			Number of samples	Deformation modulus MPa			Number of samples
	mean	max	min	mean	max	min		mean	max	min	
BST	2.8	3.3	2.4				9	180	1100	20	29
Pit gravels	7.4	9.0	4.8	60	85	40	5	540	2600	50	15
CSTB	-	-	-	-	-	-	-	6600	12600	3300	15
Cement Stabilized SSub	11.1	12.8	7.6	200	280	160	6	2400	8300	220	13
SSub	-	-	-	24	25	19	9	200	900	55	29

4 A FEW PROBLEMS WITH MANUAL FOR COMMUNITY ROAD

As organizing the data obtained by process of building the community roads at Baganuur, ‘Manual for Community Road with Bituminous Surface Treatment’ was prepared (JICA, 2006). Because we do not have enough space to describe everything about this compiled Manual, we introduce a few typical items and their problems related to constructions of CSTB as well as thickness designs of pavements.

4.1 On construction of CSTB

In a stage of spreading cements on the layer to be stabilized, it was often necessary to take measures against scattering of cement powders, caused by a gale due to the characteristic weather in Mongolia. Those are closely related to the overdesign factor of cements, such as the gale, water content of the layer, and degree of mixing by using motor grader.

From DCP tests, it was found that the thickness of each course varied widely, besides, the average thickness of both the pit gravels and the cement stabilized SSub were below the required thickness. In the case of the pit gravel, the cause for the above serious problems seems to be insufficient supply of materials, excavated and transported from quarries to job sites. This is concerned with soil conversion factors (in a sense, thickness conversion factors), which is shown a ratio of the volume of loosed materials to that of compacted original materials. Both overdesign factor of cements and the soil conversion factor should be magnified, taking Mongolian affairs into consideration.

On the thickness of cement stabilized SSub varying widely and being below the requirements, the conceivable reasons seem to be the factors, such as cement mixing by the motorgrader, cement spreading by hand, water spaying by sprinkler trucks and participations of the unskilled Gher residents in the works, either individually or in combination. Those indicate how difficult it would be for road engineers and Gher residents to have the skill of the cement stabilization learned through a short-term training, and it is a matter of the project management on the skill training, budgetary allocations and/or extension of the construction period in the working site and so on.

4.2 On thickness designs

Thickness design in the compiled Manual was based on Japanese ‘Manual for Asphalt Pavement’, in which thickness of each course of the pavements is determined on referring to T_A (similar to Structural Number) and Conversion coefficient (similar to Layer coefficient)

(JRA, 2006). Each course except BST in the community road was presumed to have the same coefficient as that in the Japanese Manual. BST was excluded from calculation of T_A.

The Japanese Manual are essentially meant for application in rather mild to moderate climate and don't take into account the kind of pavement distress caused by the severe winter climate typical of Mongolia. The predominant types of damages observed on asphalt pavement in Mongolia are shrinkage cracking, subgrade heaving and spring-thaw. Therefore, the thickness design method in the compiled Manual should be modified and strengthened, when necessary, to provide protection against the damaging effects of frost and other cold climatic conditions prevailing in Mongolia.

Comparing the deformation moduli of each course, calculated by means of LFWD method, to existing data noted widely in this kind analysis, these two were numerically almost equal. Values of IRI at the time of three years after the completion of construction showed that the surface kept at the level of 'smooth paved road'. Furthermore, to date, five years after the completion of construction, no evidence of damage to the community roads is found. It means that the pavement structures, consisted of SSub, CSTB, and BST, were suitable technically for pavements of the community road in the Gher districts. It is considered consequently that the intended assumption, (that is, each course of the community road have the same coefficient as that in the Japanese Manual), did not involve any inconsistencies at the time of five years after commencement of service.

5 CONCLUSIONS

From the facts described above on constructions of test roads, follow up investigations and indoor tests, we may conclude as follows.

Cement stabilized granular materials are of much practical use for CSTB in domestic roads, even if it was mixed in place by motorgrader and exposed under the severe weather in Mongolia. However, these materials are unsuitable to use for CSTW.

On 'Manual for Community Road with Bituminous Surface Treatment' prepared in 2006, the problems, encountered on applying the compiled Manual into practical use, are at least these two which are the overdesign factor of cement contents and the soil conversion factor. Both the factors should be modified and magnified, taking Mongolian affairs into consideration in the near future.

The intended assumption, (that is, each course of the community road have the same Conversion Coefficient as that in the Japanese Manual), do not involve any inconsistencies to date, the time of five years after commencement of service.

The possibility of applying LFWD method to the evaluation of the pavement structures of the community road was increased, even if the structure includes BST and CSTB, which are made of thin and hard materials.

New JICA project of 'Transfer of Technology to Develop Community Road Leading to Job Opportunity for Participating Residents' is conducted from 2007 to 2010 (Yano, 2009). The community roads were constructed in 2008 and 2009, respectively. We will carry out the follow up investigations in these community roads.

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