Fluvial sand and gravel aggregates of South Korea

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Abstract: A GIS modelling of fluvial aggregate has contributed to the adequate site screening process of fluvial aggregate development. GIS-supported digital mapping and GIS-DB are based on integrated modelling of natural fluvial aggregates. For modelling sand and gravel resources, it is fundamentally important to classify surficial deposits. Some quantitative and qualitative parameters obtained from fluvial deposits are statistically analysed to get independent parameters, which, in turn, characterise the fluvial aggregate resources potentials. For an economic development of fluvial aggregate the various thematic maps and integrated aggregate potential map will be helpful for aggregate extraction.

Résumé: La modélisation de l'ensemble en base de GIS ont contribuée au procés de la sélection des sites appropriés pour le dévèlopment des sables et des graviers. Les parametres quantitatives et qualitatives obtinés des dépots fluviales sont statistiquement analysés pour obtenir les parametres indépendent des potentiales de l'ensemble. Pour le dévèlopment économique de l'ensemble fluviale les plans thématiques et les plans potentials de l'ensemble sera utiles pour l'extraction des sables et des graviers.

Keywords: aggregate, river and stream, sand, gravel, land use, surface mining

INTRODUCTION

In the course of development of river aggregate resources in Korea, it became very necessary to investigate old river-bed deposits, both horizontally and vertically, and to map them in detail. Because the present river-bed is highly controlled for fluvial environmental protection and conservation, the present river-bed aggregate is developed only when local flooding hazard mitigation measurement has to be applied to the bank construction or artificial river-bed lowering. Since 2000, the present river-bed is not permitted in several major fluvial systems near metropolitan cities of Korea, even though the total consumption of present river-bed aggregate is still larger than that of old river-bed, the consumption of the latter is more or less 10 % of total consumption in Korea. In future Korean government authorities are recommended to prepare for the shortage of future fluvial aggregate production, and make a plan to map the potential of old-fluvial aggregate in major river systems in Korea. In the Preliminary surveys for the old river-bed aggregate resources include outcrop observations, trenching and boring at the prospect areas, as well as geodetic surveys and geophysical surveys in order to obtain the horizontal and vertical potential areas of old fluviatile sand and gravel deposits. These areas were assessed with explanation for further sand and gravel exploration. The properties of fluviatile aggregates were characterised with the help of laboratory test for samples collected from surficial fluviatile deposits, excavating and trenching sites along the old river-beds. To evaluate the quality of aggregates, specific gravity, grain-size distribution, absorption, materials finer than No.200 sieve, organic impurities, abrasion, and particle shape were obtained as the physical properties of riverbed sands, which are so important to maintain the quality of construction raw materials. The resources potential for old riverbed sand and gravel aggregates of the Chungnam Province of Korea were mapped based on GIS-thematic mapping tools, and evaluated their resources character both in quantity and quality. The environments of river-bed aggregates are composed of old river bottom sands and gravels, overbank sands, fluvial terrace sands, sand bodies derived from alluvial plain and alluvial fan. Finally for thematic mapping of the aggregate resources, such parameters as thickness of sand and gravels, thickness of topsoil, thickness of total alluvial deposits and resource area were taken into consideration. These parameters are independently related to one after another on the basis of varimax principal component analysis with Kaiser normalisation. The sand and gravel thickness in the alluvial deposits are calculated with other parameters mentioned-above in 95% of significance level of probability. The sand and gravel resources characterisation is determined by combining parameters of surficial deposits and socio-economic parameters like infrastructure of developing aggregates, as well as local land use practices.

Table 1. Supply and demand of aggregates in Korea

Aggregate Type	1996	1997	1998	1999
Demand (A)	214,966	221,787	191,030	168,368
Supply (B)	168,337	184,006	139,593	149,028
B/A(%)	78.3	83.0	73.1	88.5
River	51,134	48,564	25,371	36,556
Old River	14,814	13,121	7,495	7,800
Crushed	70,232	88,968	98,910	87,890
Marine	32,157	33,356	7,817	16,782

Over the last decade, the Korean construction industry has seen rapid expansion. The construction permission area (thousand m^2) is proportionally increased both to REMICON production (thousand m^3) and aggregate consumption for REMICON (thousand m^3) as shown in Figure 1, except during 1998 to 1999 when Korean economy was in decline during the IMF period.

For the last four years Korea Institute of Geosciences and Mineral Resources (KIGAM) had an experience of digital mapping of old river-bed aggregate resources. Old river-bed aggregates are very important extractable aggregate resources, even though the percentage is less than 10 % of all the consumption in Korea. KIGAM's research of old river-bed aggregates is composed of horizontal and vertical mapping of old river-bed deposits on the basis of the data acquired from trenching, drilling, geodetic and resistivity surveys, and borehole-logging.

The surface geology of fluvial aggregate potential is evaluated on the basis of latest Pleistocene fluctuation of fluvial environment of Korea. These fluvial environmental fluctuations of the latest Pleistocene deposits were analysed on the basis of fluvial deposits of post-LGM. Several fluvial deposits show a similar sedimentary depositional facies. The terrestrial post-LGM sequences show millenium-scale fluctuation of fluvial environmental changes and respond to the cyclic sequences of fluvial sands and gravels which are good for fluvial aggregates, even though they are intercalated with backswamp organic muds, and flooding muds with some horizons of paleosols. These modelling of fluvial deposits, as a preliminary data, provided us with the thickness of extractable sand and gravel, the thickness of overburdens, the total amount of fine materials less than 200 micron, and so on, which are so important parameters for any preliminary estimation of fluvial aggregates.

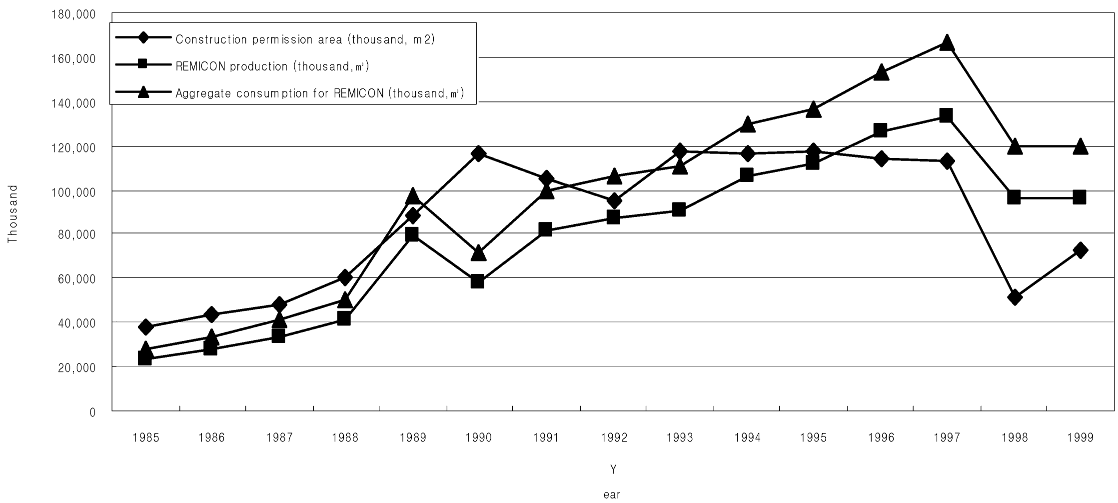

Figure 1. Relation of construction permission area (thousand m^2) both to REMICON production (thousand m^3) and aggregate consumption for REMICON (thousand m^3) in the period between 1985 to 1999.

Table 2. Aggregate potential investigated for 10 years' period.

Survey Years	Aggregate Type	Area (km^2)	Reservoir (thousand km^2)	Mining amount (thousand m^2)
1993~ 2002 (10 years)	Fluvial	3,306	6,971,808	4,388,832
	Crushed	1,738	5,530,743	3,900,164
	Marine	25,000	3,810,067	1,419,119
	Total	30,044	16,312,618	9,708,115

CLASSIFICATION OF FLUVIAL DEPOSITS

In Korean peninsula, Holocene alluvial and/or fluvial deposits occupies quite a large surface area, while upper Pleistocene fluvial deposits are less developed apparently, except coastal, old fluvial and hillslope areas. As to the latter deposits, terrace sequences were formed during the upper Pleistocene (since ca. 125ka). Marine terraces in coastal areas and/or fluvial terraces along main river courses are prevailed mostly at the level of about 10-20 m above base level (mean sea level, or river bottom) (Lee 1987). During the last glacial period, however, slope processes were developed along the foothill of mountain slopes. But the most outstanding depositional sequences are latest Pleistocene and Holocene alluvial to fluvial deposits, filled in the drowned valleys along the coastal area or at inland alluvial plain.

Old fluvial sequences (pre-LGM)

During the early last glacial period, the major rivers prograded towards the Yellow Sea, and this Sea was almost disappeared at the LGM, ca. 18ka, when sea level was almost dropped at the level of about 120 m below the present sea level (Lee et al, 1992). After LGM, the sea level abruptly rose up due to the rapid melting of ice around the polar region. Three major geomorphic responses during the last glacial time period were marked by firstly, the formation of sedimentary sequences derived mostly from mass movements, which were prevailed along the previous hill slopes or at the foot of mountain, secondly, the formation of fluvial/backswamp deposits during interstadial, and thirdly, several conspicuous horizons of soil wedge formations developed in various depositional sequences formed during the last glacial maximum. The older soil wedge structures were interpreted to be developed in the period equivalent to the marine isotope age 4, that is, ca. 65ka, while the younger ones to the marine isotope age 2, ca. 18ka (Kim et al. 1998). Soro-ri fluvial sequences are illustrated as an example of pre-LGM fluvial sequence. They are composed of fluvial gravel, sand and organic muds. The fluvial deposits are interpreted to be associated with backswamp organic muds. The formation age of Middle fluvial sequence is older than 36,000 yr BP (Kim et al. 2002, Lee et al. 2002a, 2002b). Estuarine fill sequence in the Yeongsan River mouth is another example, based on 20 m (20.50-9.50 m in depth) of MW-1 core. They are composed of lower fluvial coarse sands and pebbles, with levee/backswamp homogeneous mud, partly cross-laminated mud, and massive sand (38-29ka), and upper floodplain brown-mottled clayey silt with some sand layers (flooding paleosols, 29-27ka).

The Latest Pleistocene young fluvial sequences (post-LGM)

The latest Pleistocene fluvial sequence after LGM is exemplified in Jangheung-ri site and Soro-ri site (Kim et al. 2003, Kim et al. 2002). In the former site it is subdivided into 2 typical sequences, based on the lithofacies and radiocarbon ages. They are young fluvial sands and gravels, and backswamp organic muds. The lower part of post-LGM sequence is typified by young fluvial sand and gravel that were formed by rather perennial streams. The middle part of post-LGM sequence, however, is characterized by organic muds, particularly formed after 12-14ka. Local backswamp were flourished with organic muds and graded suspension materials in the flooding muds were intermittently accumulated in the organic muds until ca. 11ka. This episode was associated with migration of Nam River toward present course. Organic muds were formed in backswamp or local pond. This period is characterized with B lling, Older Dryas, Allerod, and Younger Dryas (MIS-1). As for latter site, Soro-ri area of Miho River valley shows also post-LGM Soro-ri organic muds and the formation age of them are 15-12ka. Pollen zones are divided into three from bottom to top.

AGGREGATE MODELLING

Quality of fluvial aggregate

To control the quality of the old river-bed aggregates, laboratory tests of samples derived from surfacial fluvial deposits, excavating sites and trenched sites along the old river-beds, as well as from boring sites, is subsequently followed. Each sample was tested for their specific gravity, grain-size distribution, absorption, and materials finer than No.200 sieve, organic impurities, abrasion, and particle shape. The physical properties are important to maintain the quality of construction raw materials. Grain size analysis of fluvial sands showed that sands of 14 out of 22 borehole in Chungnam Province are good in size characteristics, that is, 2.41-3.19 in fineness modulus. Samples of the rest boreholes have a large quantity of fine materials, derived from genetically tidal and estuarine environment prevailing at the downstream part of the river. In Chungnam Province, the content of total fine materials (passing No 200 sieve) in the sand and gravel deposits were extremely variable, vertically and horizontally, among different depositional environments. Only 3 borehole samples have less than 3%, which is a limit of Korean Standard. The fine materials have to be eliminated properly before manufacturing concrete in order to maintain the durability and strength of cement-aggregate reaction. The density of fluvial sand aggregates ranges from 2.48-2.71, and moisture content less than 3.0, which are adequate for fine aggregate.

Quantity of fluvial aggregates

Mining amount of old river-bed aggregate resources of the Chungnam Province is provided (Kim et al. 2001). In total, potential amount of old river-bed aggregate resources is 1,244,556,000 m^3 in the surface area of 424,503,000 m^2. Among them, 947,514,000 m^3 of aggregates will be possible mined. So a proved amount of sand and gravel aggregates is assessed as 434,580,000 m^3, which is equivalent to 35% of total potential amount.

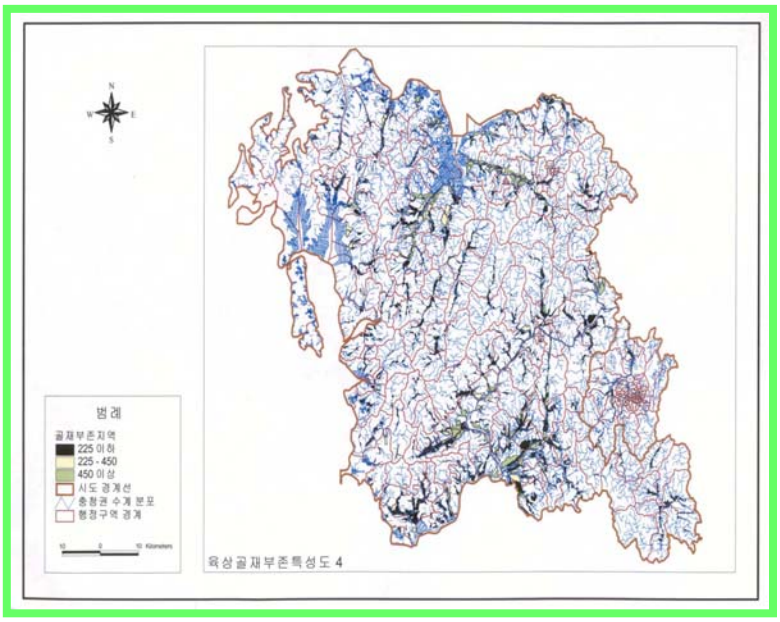

Figure 3. Aggregate potential map in old fluvial deposits.

Socio-economic analysis

Some socio-economic parameters, like the aggregate extracting company or ready-made in concrete (REMICON) company, are first of all taken into considered to optimise aggregate resource area and aggregate consumption area. All the fluvial aggregate data are analysed on the basis of 14 autonomous municipalities, drainage management system, surficial geology and geomorphology, and so forth. They are statistically analysed to get any independent parameters to characterise the fluvial aggregate resources potentials.

RESULTS AND CONCLUSIONS

In Korea, for the last four years, KIGAM had an experience of digital mapping of old river-bed aggregate resources. Now it is very important extractable aggregate resources in an aspect of environmental preservation, even though the percentage is less than 10 % of all the consumption in Korea. KIGAM's research of old river-bed aggregates is composed of horizontal and vertical mapping of old river-bed deposits on the basis of the data acquired from trenching, drilling, geodetic and resistivity surveys, and borehole-logging. The preliminary data is analysed to get the idea of the thickness of extractable sand and gravel, the thickness of overburdens, the total amount of fine materials less than 200 micron, and so on, which are so important parameters for any preliminary estimation of fluvial aggregates. An evaluation of fluvial aggregate resources potential of Chungnam Province was illustrated on the basis of modelling and quality controlling of sand and gravel aggregate resources (Kim et al. 2001). GIS-supported digital mapping and GIS-DB were important to make an integrated management system and quality control of natural fluvial aggregates. All the information on the fluvial aggregate resources is to be linked to web-server and disseminated to interest partners. Modelling for GIS-DB of sand and gravel resources is fundamentally related to the genetic classification of surficial geology and micro-geomorphology. For fluvial aggregate modelling, it is primarily important to classification of Quaternary depositional sequences since the Last Glacial Period. Digitising mapping tools were used to produce several thematic maps.

For the quality control and GIS-DB of fluvial aggregate, laboratory test of samples derived from surfacial fluvial deposits and excavating and trenching sites along the old river-beds, as well as from boring sites, are subsequently followed: samples were tested for their specific gravity, grain-size distribution, absorption, and materials finer than No.200 sieve, organic impurities, abrasion, and particle shape. These physical properties are important to maintain the quality of construction raw materials. Normally density of fluvial sand aggregates ranges 2.48-2.71, and moisture content less than 3.0, which are adequate for fine aggregate. Grain size analysis of fluvial sands showed that sands of 14 out of 22 borehole in Chungnam Province are good in size characteristics, that is, 2.41-3.19 in fineness modulus. Samples of the rest boreholes have a large quantity of fine materials, derived from genetically tidal and estuarine environment prevailing at the downstream part of the river. In Chungnam province, the content of total fine materials(passing No 200 sieve) in the sand and gravel deposits were extremely variable, vertically and horizontally, among different depositional environments. Only 3 borehole samples have less than 3%, which is a limit of Korean Standard. The fine materials have to be eliminated properly before manufacturing concrete in order to maintain the durability and strength of cement-aggregate reaction. Before link to web-server, all the fluvial aggregate data are analysed on the basis of 14 autonomous municipalities, drainage management system, surficial geology and geomorphology, and so forth. As an example, mining amount of old river-bed aggregate resources of the Chungnam Province is provided. In total, potential amount of old river-bed aggregate resources is 1,244,556,000 m^3 in the surface area of 424,503,000 m^2. Among them, 947,514,000 m^3 of aggregates will be possible mined. So a proven amount of sand and gravel aggregates is assessed as 434,580,000 m^3, which is equivalent to 35% of total potential amount.

Finally, fluvial aggregate potential in South Korea has been evaluated for the last 10 years. Aggregate industry is closely connected with the fluvial deposits and aggregate reservoirs. Quantity and quality of fluvial aggregates have been evaluated on the basis of detailed geoscientific surveys and laboratory tests. The development of fluvial aggregate resources has been complicated with socio-economic factors related to the human management practices of land surface. Modern artificial constructions in the fluvial areas, since the 20th century, including heavy construction of banks, dams drove people into an excessive use of aggregate resources. The resources evaluation of fluvial aggregates derived from present and old river beds has been important constructional raw materials in South Korea. It supplies for about 25% of national aggregate consumption, next to crushed aggregates. Recently, a GIS modelling of fluvial aggregate has contributed to the adequate site screening process of fluvuial aggregate development. In particular, GIS-supported digital mapping and GIS-DB are an important tool to make an integrated modelling of natural fluvial aggregates. For modelling sand and gravel resources it is fundamentally important to relate genetical classification of surficial deposits to micro-geomorphology of fluvial system in a drainage basin. Some quantitative and qualitative parameters obtained from fluvial deposits are statistically analysed to get independent parameters, which in turn characterise the fluvial aggregate resources, potentials. Fluvial aggregate data is analysed on the basis of autonomous municipalities, drainage management system, surficial geology and geomorphology. For an economic development of fluvial aggregate the various thematic maps and integrated aggregate potential map will be helpful in the future aggregate extraction of aggregate. An over-extraction of fluvial aggregate has resulted to the lowering of equilibrium height of river-bed, even though it partly contributes to diminish flooding damage. Over-management, i.e., artificial rising or decreasing of the equilibrium height of the current river bed, may cause artificial flooding damages. Thus, it is concluded that any fluvial aggregate extraction is examined with multiple points of view.

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REFERENCES

KIM, J.Y. & 23 OTHERS. 2001. *Investigation of Industrial Stones and Aggregate Resources*. KIGAM Research Report RS-01(C)-05, 1-550.

KIM, J.Y., LEE, D.Y. & CHOI, S.G. 1998. A Research on Pleistocene Stratigraphy. *Korean Journal of Quaternary Research,* **12**, 77-87.

KIM, J.Y., LEE, Y.J., YANG, D.Y., KIM, J.C., BONG, P.Y. & PARK, J.H. 2002. Quaternary geology and vegetation environment of Sorori Palaeolithic site - in comparison to Jangheungri site in Jinju.*In : Preceedings of the 1st International Symposium: Prehistoric Cultivation in Asia and Sorori rice*, 26-30.

KIM, J.Y., PARK, Y.C., YANG, D.Y., BONG, P.Y., SUH, Y.N. & LEE, Y.S. 2003. Formation environment of Quaternary deposits and palynology of Jangheung-ri Archaelogical Site (Jiphyeon County, Jinju City), Korea. *Korean Journal of Quaternary Research,* **16** (2), 1-10.

LEE, D.Y. 1987. Stratigraphic research of the Quaternary deposits in the Korean Peninsula. *Progress in Quaternary Geology of East and Southeast Asia, CCOP/TP-18*. 227-242.

LEE, D.Y. & KIM, J.Y. 1992. Review on the Quaternary stratigraphy of the Korean Peninsula. *The Sino-Korean Symposium of Quaternary and Prehistory,* 69-99.

LEE, Y.J. & WOO, J.Y. 2002a. On the Oryza sativa and peat layers in the Palaeolithic Period from Sorori in Cheongwon, Korea. *In: Proceedings of Suyanggae and her Neigbours-the 7th International Symposium*, 149-156.

LEE, Y.J. & WOO, J.Y. 2002b. Excavation of the Paleolithic Sorori Rice and its important problem. *In: Proceedings of the 1st International Symposium: Prehistoric Cultivation in Asia and Sorori rice*, 17-23.