Chemical Study of the Raw Material in Gandghar Range, District Haripur, NWFP, for Portland Cement Manufacturing

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Summary: Limestone is a valuable raw material, which is widely used in the chemical, metallurgical and construction industries throughout the world. With huge deposits of limestone in Pakistan, it is immensely used as the major raw material in the cement manufacturing. The extensive deposits of limestone are exposed in the Gandghar, Cherat and Khyber ranges around the Peshawar basin. The area of study was a part of the Gandghar range in District Haripur in Hazara where various types of raw materials (i.e., limestone, phyllite and clay) used in the cement manufacturing are present. This raw material was analyzed for the major element oxides and its chemistry was evaluated in regard to the manufacturing of portland cement during this study. It was found that the raw mixture in the proportion of 80 % of Shekhai limestone, 2 % of Utch Khattak limestone, 3 % of greenish-grey limestone, 12 % of clay and 3 % of laterite resulted in the final product of clinker having 22.57 % SiO_2, 4.84 % Al_2O_3, 4 % Fe_2O_3 and 67.09 % CaO. This clinker has the appropriate composition for the manufacturing of portland cement. It is, therefore, recommended that a feasibility study should be conducted for establishing portland cement manufacturing plant in the area for the best use of the studied raw material of the Gandghar range.

Introduction

Limestone is a sedimentary rock composed of calcium carbonate. The two most important constituents are calcite ($CaCO_3$) and dolomite ($CaMgCO_3$), but it also has a small amount of iron bearing carbonates. It can be classified into three major groups; organic, chemical and detrital or clastic. Many of the commonly occurring limestones contain organic, detrital and chemically precipitated materials in varying proportions. Limestone is one of the raw materials used for cement manufacturing. In addition to other raw materials such as chalk, clay, marl and shale, limestone is also used in other metallurgical and chemical industries such as in lime burning, metallic calcium and its alloys, calcium hydride, alkali manufacturing, sugar refining and paper manufacturing etc.

Pakistan has great resources of limestone, which can be utilized for cement manufacturing. There are extensive limestone beds, exposed in many areas of Pakistan, e.g., Nizampur area, district Nowshera, Kohat district, Haripur district, Dera Ismail Khan division, Hyderabad division, Lockhart and Margalla hills.

The area of study is located in the Haripur district of North West Frontier Province (NWFP) and is the part of the Gandghar Range (Fig. 1). The limestone deposits of Gandghar Range, are of two types, Shekhai and Utch Khattak Formations [1]. The Shekhai Formation is exposed in the south-eastern part of the north Gandghar Range in Hazara division. This formation is mainly composed of limestone, marble with subordinate argillite, shale and quartzite. The limestone varies in color from grey, light-brown to pink and is fine-grained and thin to medium-bedded. This limestone is widely exposed in the area. However, at certain places, greenish-grey limestone is also exposed. The Shekhai Formation has been assigned a tentative Late Precambrian age [2]. The exposures of Utch Khattak Formation are restricted to the south-eastern Gandghar Range and are mainly composed of limestone, argillite and shale. It is blush-grey to dark-grey in color and is generally fine to medium-grained and thin-bedded. The Utch Khattak Formation is conformable with the underlying Shahkot Formation and overlying Shekhai Formation [2, 3]. It has also been assigned a tentative Late Precambrian age [2].

There are huge reserves of Shekhai and Utch Khattak limestone in the Gandghar Range in addition to phyllites, slates, shales and clays. Among these raw materials, the limestone of the area is used as

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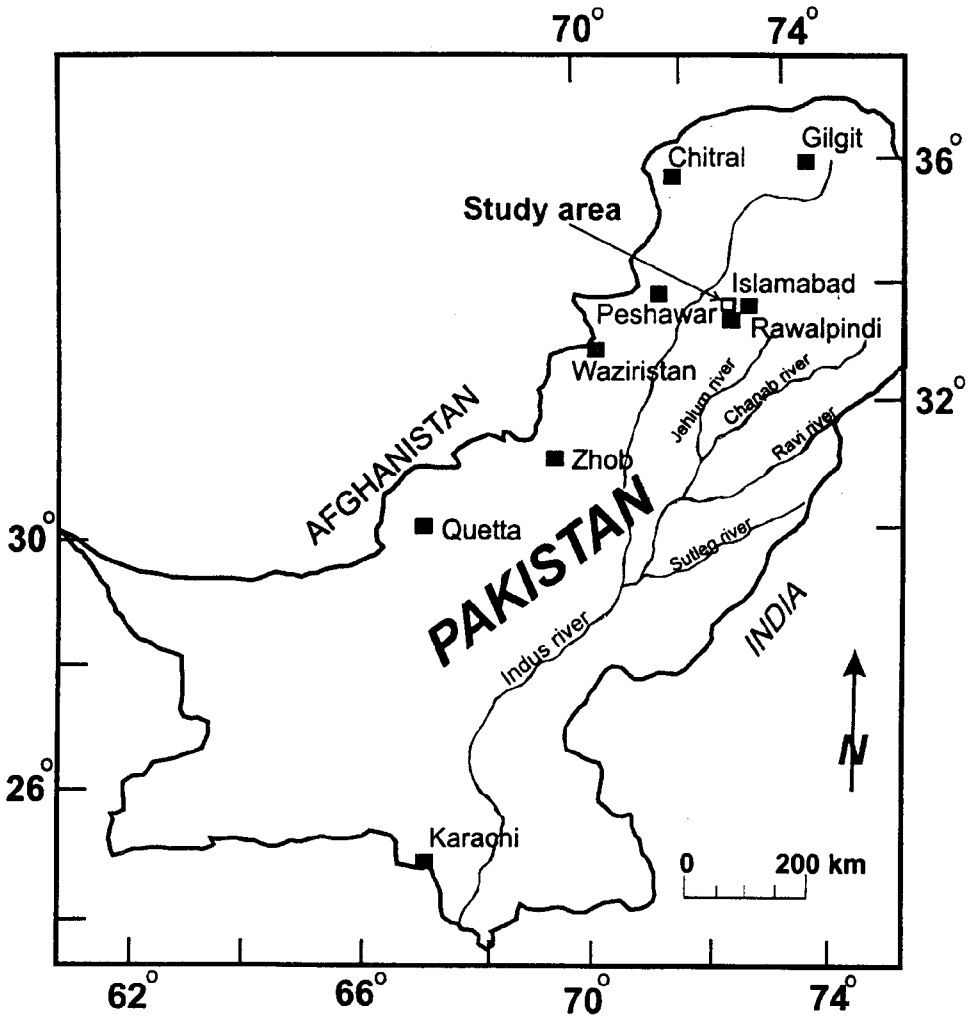

Fig. 1. Map showing the location of study area.

crushed aggregates for road and building construction. However, no scientific studies have been carried out on these limestones and associated phyllites and clays in regard to cement manufacturing. This study, therefore, deals with the chemical characterization of limestone of Gandghar Range and associated lacustrine clay as well as shale and phyllites for cement manufacturing.

Raw Material for Cement Manufacturing in General

Cement raw materials may be divided into four groups namely, calcareous, supplying lime; siliceous, supplying silica; argillaceous, supplying alumina; and ferriferous, supplying iron [4]. Gypsum in very small amount is required to control the setting time of cement. Thirty different (a) rock-materials can be used in the manufacturing of Portland cement. The calcareous materials include: cement rock, limestone, marl, alkali waste, chalk and marble. The argillaceous materials include: clay, shale, slage, fly ash, copper slag, aluminum ore refuse, clay, and Kaolin. The siliceous materials include: sand, trap-rock, quartzite and calcium silicate. The ferriferous materials include: iron dust, iron sulfides, iron smelters, iron oxide, and blast furnace flue dust. The cement rock is an ideal low-magnesium bearing calcareous limestone with such a composition that it may be used for cement manufacturing without any addition of other earth materials or with an addition of only a relatively small amount of earth materials.

Proportioning of Raw Material for Cement Manufacturing

The mineral constituents of cement and their average percentages are: Tricalcium silicate (C_3S) = 50 %, Dicalcium silicate (C_2S) = 25 %, Tricalcium Aluminate (C_3A) = 10 %, Tricalcium Aluminaferrite (C_3AF) = 10 % and Other compounds = 5 %. The limits of composition of portland cements are approximately: CaO = 60-67 %, SiO_2 = 17-25 %, Al_2O_3 = 3-8 % , Fe_2O_3 = 0.5-6.0 %, MgO = 0.1-5.5 %, $Na_2O + K_2O$ = 0.5-1.3 % and SO_3 = 1-3 % (Lee, 1976)

The silica in a portland cement form, with lime, the essential cementing compounds such as C_3S and C_2S. Any change in the silica content increases the proportion of C_3S, which affects the early strengths of cement favorably. An increase in silica content at the expense of the content of alumina and ferric oxide make the cement harder to clinker and its setting time easier to control. An increase of silica, at the expense of the lime content, reduces the rate of development of strength. The increase of alumina with no change, or with a reduction in the ferric oxide content, hastens the setting of cement and a point is eventually reached at which it becomes impossible to control the setting time adequately. Magnesia (MgO) in most British Portland cements, is averaging around 1 percent, but in many foreign cements, it may rise to 3-4 percent. Specifications in all countries place a maximum limit, usually 4-5 percent, on the permissible content of MgO, because higher contents lead to long-term unsoundness. It has also been claimed that still higher contents of MgO can be tolerated in cements of high iron oxide content [5]. Alkalis ($Na_2O + K_2O$) always present in amounts varying from < 0.2 to 1.3 %. There are other various minor constituents (TiO_2, Mn_2O_3 and P_2O_5 etc.) varying in amount from a trace to 1.5 %. Titanium oxide (TiO_2) is commonly present to the extent of 0.1-0.4 %. However, it may rise to 1 %. Manganese oxide (Mn_2O_3) is present to an extent of 1 % or above in portland cements made from a blast furnace. Elements such as barium and strontium are usually present in small amounts, below 0.05 % for BaO and 0.2 % for SrO. The content of chromium oxide, though small, is of particular significance in relation to the incidence of cement dermatitis.

Results and Discussion

Chemistry of Shekhai Limestone

The major element chemistry of Shekhai Limestone is given in Table 1. It is evident from this table that these limestone samples have SiO_2 in the range of < 4.89 to 18.34 %, Al_2O_3 is up to 1.31, Fe_2O_3 is less than 2.02 %, MgO ranges from 0.78 to 4.68 %, and CaO ranges from 40.30 to 52.40 %. Among alkalis, Na_2O is less than 0.20 %, while K_2O is less than 1.30 %. The loss on ignition (LOI) ranges from 33.34 to 38.78 %. The average composition of Shekhai limestone is such that SiO_2 is 8.33 %, Al_2O_3 is 0.81 %, Fe_2O_3 is 1.08 %, CaO is 50.26 %, MgO is 2.23 %, Na_2O is 0.10 % and K_2O is 0.78 % (Table-1).

SiO_2 in various forms is present as impurities in the limestone, for example in cement stone and cherty limestone [6]. The Shekhai limestone has variable amounts of SiO_2. It generally has low concentration of SiO_2 and is in the range of normal limestone; but at places, the SiO_2 content reaches upto the maximum of about 18 % and is classified as argillaceous limestone. Alumina (Al_2O_3) is the second largest impurity in the limestone. Both the alumina and silica concentration in the limestone usually originate from the shaly matters [6]. The Al_2O_3 content of studied samples is generally less than 1.3 % (Table-1). Iron, in the form of oxides and sulfides, occurs as impurity in the limestone, which if present in higher amount, can cause deterioration in the building construction. In limestone, iron can be

Table-1. Chemical Composition of the Shekhai limestone of the Gandghar Range (all values are in %).

Sample No.	SH41	SH61	SH19	SH85	SH11	SH94	SH84	SH25	Average
SiO_2	4.89	6.23	12.34	6.34	18.34	5.45	6.23	5.34	8.33
Al_2O_3	0.78	0.67	0.87	1.23	1.31	0.53	0.56	0.54	0.81
Fe_2O_3	1.23	1.12	2.02	0.87	0.76	0.78	0.39	1.46	1.08
MgO	2.12	2.12	1.23	0.78	4.68	2.67	2.45	1.84	2.23
CaO	52.2	51.34	48.67	52.34	40.30	52.40	52.20	52.20	50.26
Na_2O	0.07	0.08	0.20	0.06	0.19	0.06	0.07	0.07	0.10
K_2O	0.43	0.14	1.30	0.13	1.23	0.29	0.43	0.36	0.78
LOI	38.43	38.78	33.34	38.45	34.32	38.45	38.76	38.12	37.33
Total	100.15	100.48	99.97	100.2	100.59	100.63	101.09	99.93	100.98

homogeneously disseminated during chemical displacement of the calcium bearing iron carbonate or heterogeneously distributed through iron bearing strata. The Fe_2O_3 contents of the studied limestone are generally less than 2 % (Table-1). Magnesium oxide (MgO) in the limestone is a function of both the magnesium content of skeletal debris and also the other dolomitization processes due to post depositional events [6]. The increase of MgO, therefore, increases the dolomitic component of limestone. Dolomite can not be used in the manufacture of portland cement because of its high magnesium. The MgO contents of the Shekhai limestone are generally less than 5 % (Table-1). Calcium oxide (CaO) is the highest constituent of limestone. The replacement of CaO by MgO in limestone is the indication of dolomitization of limestone [6]. The Shekhai limestone samples of the studied area generally have more than 45 % of CaO, which is the normal range of limestone. One sample, however, has less than 45 % CaO, which is due to the siliceous nature of this limestone. This increase or decrease of CaO in the studied limestone is, therefore, related to silica (SiO_2) concentration rather than MgO. Sodium oxide (Na_2O) and potassium oxide (K_2O) are considered as traces with respect to the pure limestone chemistry [7]. Na_2O and K_2O in the studied limestone are in the range of normal limestone but in one sample, K_2O increases to more than 1 % which could be due to the input of argillaceous material (Table-1). During the determination of loss on ignition (LOI), the bond between $CaCO_3$ molecules is broken to form lime (CaO) and CO_2. This CO_2 is the measure of ignition loss. It ranges from 33.34 to 38.78 %.

Chemistry of Utch Khattak Limestone

The major chemical element of the Utch Khattak Limestone, is given in Table 2. The SiO_2 content in the samples is generally high in the Utch Khattak limestone. It is in the range of 4.40 to 23.7 %, Al_2O_3 is in the range of 0.56 to 2.31 % and Fe_2O_3 is less than 2.44 %. MgO ranges from 1.61 to 3.91 % and CaO from 38.60 to 50.30 %. Among alkalis, Na_2O is less than 0.66 % while the K_2O is less than 1.56 %. The loss on ignition ranges from 28.71 to 40.24 %.

SiO_2 and Al_2O_3 in these samples are high as compared to that of Shekhai limestone, which suggest the detrital input in these limestones. Fe_2O_3 contents of studied limestone vary between 0.29 and 2.49. MgO content of studied limestone in Utch Khattak is similar to that of Shekhai limestone. CaO in Utch Khattak limestone is also low as compared to that of Shekhai limestone of the area. Its concentration generally varies with an increase and decrease of SiO_2. Na_2O and K_2O are very low (< 1.70 %) in total and more or less constant in almost all the samples.

Chemistry of Greenish Gray Limestone

The major chemical element of greenish-gray limestone is given in Table 3. The SiO_2 ranged from

Table-2: Chemical Composition of the Utch Khattak limestone of the Gandghar Range (all values are in %).

Sample No.	UK89	UK96	UK90	UK92	UK104	UK93	UK98	UK95	Average
SiO_2	5.61	10.10	23.70	11.35	4.40	22.10	20.60	10.10	13.49
Al_2O_3	0.78	1.21	2.10	1.32	0.56	2.12	2.31	1.32	1.47
Fe_2O_3	0.43	0.44	2.44	0.52	0.29	1.32	1.47	0.79	0.96
MgO	1.61	1.96	2.80	1.47	3.75	1.80	3.91	2.42	2.47
CaO	50.30	49.30	38.60	45.50	50.10	40.30	40.20	45.96	44.96
Na_2O	0.07	0.11	0.07	0.07	0.15	0.08	0.66	0.07	0.16
K_2O	0.21	0.17	0.49	0.19	0.14	1.56	0.58	0.60	0.49
LOI	40.24	38.14	30.73	38.19	40.18	28.71	31.66	38.82	35.83
Total	99.25	10.43	100.93	99.57	99.57	97.99	101.39	100.08	99.83

Table-3: Chemical composition of the greenish-grey limestone of the Gandghar Range (all values are in %).

Sample No.	GG36	GG21	GG9	GG39	GG59	GG38	GG76	Average
SiO_2	3.50	3.45	16.45	17.15	12.20	10.30	27.30	12.91
Al_2O_3	0.53	0.75	2.12	2.15	1.08	1.10	2.13	1.41
Fe_2O_3	0.40	0.28	0.76	1.70	0.53	0.61	0.61	0.70
MgO	6.91	2.56	4.43	5.69	4.64	3.58	5.55	4.77
CaO	49.90	49.60	45.20	40.30	45.52	45.30	32.96	44.11
Na_2O	0.24	0.06	0.67	0.27	0.05	0.51	0.38	0.31
K_2O	0.06	0.24	0.27	1.26	0.85	0.07	0.80	0.51
LOI	38.68	41.94	31.59	30.40	33.39	37.72	28.90	34.66
Total	100.22	98.88	101.49	98.92	98.26	99.19	98.63	99.37

3.45 to 27.3 %, Al_2O_3 from 0.53 to 2.15 %, Fe_2O_3 from 0.4 to 1.7, MgO ranged from 2.56 to 6.91 % and CaO from 32.96 to 49.9 %. Na_2O was less than 0.67 % and K_2O is less than 1.26 %. The loss on ignition ranged from 28.9 to 41.94 %. The chemistry of this limestone is similar to that of the Utch Khattak limestone. The SiO_2 content in most of the samples is high and can, therefore, be considered as siliceous limestone. Al_2O_3 is variable and is relatively higher than the normal limestone. Fe_2O_3 is generally within the range of normal limestone and occurs in variable amounts. MgO is also present in variable amounts and may reach up to about 7 %. CaO is generally within the range of siliceous limestone and it, therefore, varies with the increase and decrease of SiO_2. A greater variation in the Na_2O and K_2O contents has been observed in the studied limestone.

The average compositions, of the three types of studied limestones, are compared with that of the normal and argillaceous limestone in Table 4. It is clear from this table that all the three varieties of the studied limestone on average have more silica (SiO_2) than normal limestone. The Shekhai limestone has low SiO_2, while the Utch Khattak limestone and greenish-grey limestone have more or less similar SiO_2 as that of argillaceous limestone. Al_2O_3 and Fe_2O_3 are relatively high in the studied limestone as compared to that of normal limestone. These are, however, manifold less than that of the argillaceous limestone. MgO in the studied limestone is low as compared to that of normal limestone and high as compared to that of argillaceous limestone. The CaO is, however, high in the studied limestone as compared to that of both normal and argillaceous limestone. Total alkalies in the studied limestones are relatively high as compared to that of normal limestone but manifold less than that of argillaceous limestone.

Chemistry of Clay

The major element chemistry of clay is presented in Table 5. SiO_2 ranged from 48.00 to 52.50 %, Al_2O_3 from 15.32 to 18.42 %, Fe_2O_3 from 2.07 to 4.84 %, CaO from 8.07 to 12.64 % and MgO from 3.33 to 4.68 %. Na_2O and K_2O ranged from 0.48 to 1.52 % and 1.44 to 2.14 % respectively. The average composition of the studied clays is also compared with that of normal clay in Table 5. SiO_2 and MgO were more or less similar to that of normal clay, while other constituents were generally low in the studied clay except CaO, which is manifold higher in the studied clay as compared to that of normal clay.

Chemistry of Phyllite

The major element chemistry of phyllite is given in Table 6. It is evident from this table that the phyllite samples have SiO_2 in the range of 53.5 % to

Table-4: The comparison of average composition of the studied limestones with those of normal and argillaceous limestones elsewhere in the world (all values are in %).

Samples	Shekhai Limestone (This Study)	Utch Khattak Limestone (This Study)	Greenish Grey Limestone (This Study)	Normal Limestone [8]	Argillaceous Limestone [9]
SiO_2	8.33	13.49	12.90	5.19	13.80
Al_2O_3	0.81	1.46	1.40	0.81	7.00
Fe_2O_3	1.07	0.96	0.69	0.54	4.55
MgO	2.23	2.46	4.76	7.90	1.32
CaO	50.25	44.95	44.10	42.61	38.35
Na_2O+K_2O	0.96	0.65	0.81	0.38	3.47

Table-5: Chemical composition of clay of Gandghar Range and its comparison with the normal clay elsewhere in the world (all values are in %).

Sample No.	GRC 74	GRC 65	GRC6	GRC3	GRC 78	GRC 79	GRC 70	GRC 69	Average	Normal clay [10]
SiO_2	50.10	48.50	50.80	50.20	52.10	48.80	48.00	52.50	50.13	50.33
Al_2O	16.89	15.32	15.38	18.12	16.34	18.12	18.42	17.52	17.01	19.17
Fe_2O_3	3.34	4.84	3.81	4.43	4.62	2.07	4.34	4.26	3.96	6.50
MgO	4.25	4.06	3.77	3.35	4.58	3.33	4.68	4.53	4.07	3.77
CaO	9.00	12.64	8.20	8.60	9.16	8.07	9.86	8.13	9.21	1.43
Na_2O	0.87	1.04	1.33	1.16	1.52	0.48	1.09	1.11	1.08	0.81
K_2O	1.44	2.11	1.69	2.14	2.13	1.27	2.13	1.95	2.00	2.32
LOI	13.55	13.53	14.10	11.00	10.76	15.57	11.50	9.54	12.44	--
Total	99.44	102.04	99.08	99.00	101.21	97.71	100.02	99.54	99.90	--

Table-6: Chemical composition of Phyllite of the Gandghar Range and its comparison with the normal clay elsewhere in the world (all values are in %).

Sample No.	GRP29	GRP 31	GRP 101	GRP45	GRP 57	GRP 55	GRP50	GRP 97	GRP 75	Average	Shale [8]
SiO_2	64.50	63.70	55.00	63.60	63.80	64.20	65.50	57.80	53.50	61.29	58.10
Al_2O_3	16.12	17.64	18.86	22.72	23.12	23.52	20.12	23.65	22.38	20.90	15.40
Fe_2O_3	5.32	2.59	4.74	0.36	1.87	0.25	4.52	4.50	2.98	3.01	4.02
MgO	3.64	5.00	5.00	2.56	2.05	0.93	2.50	2.60	7.00	3.48	2.44
CaO	3.13	5.75	5.63	0.78	1.87	1.36	2.15	1.99	2.10	2.75	3.11
Na_2O	1.37	1.41	1.13	0.09	0.31	3.60	0.72	1.09	0.41	1.13	4.54
K_2O	3.53	1.89	3.04	0.67	0.89	0.55	2.30	2.00	3.13	2.00	2.12
LOI	3.18	3.26	5.08	2.53	3.51	3.20	2.63	5.11	6.85	3.93	--
Total	100.79	100.24	98.48	93.31	97.42	97.61	100.44	98748.00	88.35	98.49	--

65.5 %, Al_2O_3 from 16.12 to 23.65 %, Fe_2O_3 from 0.25 to 5.32 %, CaO from 0.78 to 5.75 % and MgO from 0.93 to 7.00 %. Na_2O and K_2O are ranging from 0.31 to 1.37 % and 0.55 to 3.53 %, respectively (Table-6). It is clear from the chemical composition of the studied phyllites that there is a greater variation in almost all the oxides. The studied phyllite samples are also chemically compared with that of normal shale in Table 6. These have high SiO_2, Al_2O_3 and MgO and low Fe_2O_3, CaO and total alkalies as compared to that of the normal shale (Table-6).

Proportioning of Raw Material for Cement Manufacturing

In cement manufacturing, the mixing of various raw materials in different proportions, is a very difficult job. Once the appropriate proportions are set then the portland cement of desired composition can be obtained. During this study, the raw materials, available in the Gandghar Range for cement manufacturing, were chemically evaluated and their mixing proportions were calculated to manufacture appropriate portland cement. By considering various types of raw materials (i.e., Shekhai, Utch Khattak and greenish-grey limestone, phyllite, clay and literates), about thirteen different mixtures with different ratios were prepared. Assuming these ratios of mixing, the approximate clinker composition and other parameters for these thirteen raw mixtures were calculated. Among these thirteen raw mixtures, the most appropriate raw mixture and clinker composition is discussed below.

Proportion of Raw Mixture

The raw material for the selected mixture includes 80 % of Shekhai limestone, 2 % of Utch Khattak limestone, 3 % of greenish-grey limestone, 12 % of clay and 3 % of laterite. Laterite is not available in the Gandghar Range but it has been included in the raw mixture for the reason that it has several advantages such as high iron contents, high corrective efficiency and the ability for better quality control. The percentage of oxides is different in each of this raw material. The average composition of SiO_2 in Shekhai limestone is 8.33 %, in Utch Khattak limestone, it is 13.49 %; in greenish-grey limestone it is 12.91 %, in clay it is 50.13 % and in laterite it is 44 %. By considering the proportion of different raw materials, the total SiO_2 in this raw mixture is calculated as 14.66 % (Table-7). The average composition of Al_2O_3 in Shekhai limestone is 0.81 %, in Utch Khattak limestone, it is 1.47 %, in greenish-grey limestone, it is 1.41 %, in clay, it is 17.01 % and in laterite, it is 12.80 %. By considering the proportion of different raw materials, the total of Al_2O_3 is calculated as 3.14 % (Table-7). The average composition of Fe_2O_3 in Shekhai limestone is 1.08 %, in Utch Khattak limestone, it is 0.96 %, in greenish-grey limestone, it is 0.70 %, in clay, it is 3.96 % and in laterite, it is 40.50 %. By considering the proportion of different raw materials, the total Fe_2O_3 is calculated as 2.60 % (Table-7). The average composition of CaO in Shekhai limestone is 50.26 %, in Utch Khattak limestone, it is 44.96 %, in greenish-grey limestone, it is 44.10 %, in clay, it is 9.21 % and in laterite, it is 1.05 %. By considering the proportion of different raw materials, the total CaO is calculated as 43.57 % (Table-7).

Once the chemical composition of the raw material is calculated, the resultant clinker composition can be calculated and is shown in Table 7. This shows that the resultant clinker will have 22.51 % SiO_2, 4,89 % Al_2O_3, 4 % Fe_2O_3 and 67.09 % CaO. This composition is within the range of Portland cement. The other parameters of the raw mixture and resultant clinker such as Modulus of Alumina (MA), Modulus of Silica (MS), Lime Saturation Factor (LSF) and Tricalcium Aluminate

Table-7: Chemical composition of studied raw material and resulted raw mixture and clinker for portland cement manufacturing (all values are in %).

	Shekhai limestone	Utch Khattak limestone	Greenish-grey limestone	Clay	Laterite	Raw Mixture (RM)	Clinker (RM x 1.54)
SiO_2	8.33	13.49	12.91	50.13	44	14.66	22.57
Al_2O_3	0.81	1.47	1.41	17.01	12.8	3.14	4.84
Fe_2O_3	1.08	0.96	0.7	3.96	40.5	2.59	4
CaO	50.26	44.96	44.1	29.21	1.05	43.57	67.09

Table-8: Various parameters calculated for the raw mixture and clinker obtained through studied raw material.

Parameters	Raw Mixture	Clinker
MA	1.21	1.21
MS	2.56	2.55
LSF	0.910	0.910
C_3A	4.05	6.23

(C3A) are calculated as follows and the results are given in Table 8.

MA for raw mixture = Al_2O_3/ Fe_2O_3
= 3.14 / 2.59 = 1.21

MA for Clinker = 4.84 / 4.00 = 1.21

MS for raw mixture = $SiO_2 / Fe_2O_3 + Al_2O_3$
= 14.66 / 2.59 + 3.14 = 2.56

MS for Clinker = 22.57 / 4.00 + 4.84
= 2.55

LSF for raw mixture = $CaO / 2.8xSiO_2 + 1.18 x Al_2O_3 + 0.65x Fe_2O_3$
= 43.57 / 2.8x14.66 + 1.18 x 3.14 + 0.65x2.59 = 0.938

LSF for Clinker = 67.09 / 2.8x22.57 + 1,18 x 4.84 + 0.65x4.00 = 0.938

C_3A for raw mixture = $2.65xAl_2O_3 - 1.65x Fe_2O_3$
= 2.65 x 3.14 – 1.65 x 2.59 = 4.05

C_3A for Clinker = 2.65 x 4.84 – 1.65 x 4.00 = 6.23

This study suggests that if the vast amount of raw material, available in the Gandghar Range, is utilized in the proportion as discussed above in a cement factory, an appropriate composition of clinker can be produced for the production of Portland cement in the area. It is therefore, recommended that a feasibility study should be conducted for the erection of cement production plant in the area for the best use of the raw material available in the Gandghar Range, which at present is generally used as a crushed material for the construction of roads and buildings.

Experimental

Sampling

Representative samples (about 1kg each) were collected from the various types of limestones, phyllites and lacustrine clay deposits of the Gandghar range during field. These samples were transferred to the Geochemistry laboratory of the National Centre of Excellence in Geology, University of Peshawar, for chemical analysis.

Analytical Procedure

The samples collected during field, were crushed and pulverized to 100-mesh size. An appropriate amount (about 50 g) of each powder sample was selected after quartering and coning technique. The samples were then dried overnight in the oven at 110 °C for further analyses. Two types (A & B) of stock solutions were prepared. Stock solution A was prepared by fusing an appropriate amount of powdered sample with NaOH in the nickel crucible and final dissolution in 1000ml de-ionized water. This solution was used for the determination of SiO_2 by the method of ammonium molybdate and Al_2O_3 by the method of 8-Hydoxyquinoline by using the Pye-Unicam UV/visible spectrophotometer (Jerry and Hutchison, 1987). Stock solution B was prepared by decomposing the appropriate powdered sample in Hydrofluoric-perchloric acids mixture and final dissolution to 250 ml with de-ionized water [11]. This solution was used for the determination of Fe_2O_3, MgO, CaO, Na_2O and K_2O by using the Perkin Elmer atomic absorption spectrophotometer. The loss on ignition was determined by heating the appropriate sample in the porcelain crucible at 950 °C in the furnace for four hours and the weight difference was calculated as loss on ignition.

Conclusion

Huge reserves of cement raw materials (i.e., calcareous and argillaceous) occur in the Gandghar Range of District Haripur. These raw materials have been chemically evaluated and various proportions of raw mixtures have been identified for the manufacturing of Portland cement. It has been determined during this study that the raw mixture in the proportion of 80 % of Shekhai limestone, 2 % of Utch Khattak limestone, 3 % of greenish-grey limestone, 12 % of clay and 3 % of laterite has been found the best raw mixture for the formation of an appropriate clinker for Portland cement. It is, therefore, recommended that a cement manufacturing plant should be established for the best use of this raw material in the area.

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