Correlations between Ev1, Ev2 and Evd and Correlation to CBR

- Ev1 – static deformation modulus or strain modulus of the first loading cycle for the bearing capacity from the Plate Load Test (PLT)
- Ev2 – static deformation modulus or strain modulus of the second loading cycle for the bearing capacity from the Plate Load Test (PLT)
- Evd – dynamic deformation modulus from the Light Weight Deflectometer (LWD) or dynamic plate load test
- CBR - the California Bearing Ratio (CBR) test is a simple strength test that compares the bearing capacity of a material with that of a well-graded crushed stone (thus, a high quality crushed stone material should have a CBR @ 100%). It is primarily intended for, but not limited to, evaluating the strength of cohesive materials having maximum particle sizes less than 19 mm (AASHTO, 2000). The ratio is measured using a standardised penetration test first developed by the California Division of Highways around 1930.

To start with, there is no general mathematical relation between CBR and plate loading test results.

- CBR is a material property test that gives you information about the strength of a small, homogeneous material sample. Results from CBR laboratory tests ideally are used as a basis to determine layer thickness of subbase and base course materials to achieve a certain bearing capacity. **For a conventional laboratory CBR test, only the top 5mm of the material in the CBR mould are tested.** CBR field tests have been used to estimate bearing capacity insitu. However, information obtained through this insitu test are valid only for a relatively thin layer on the material surface (ca. 100mm depth).
- Plate loading tests (static or dynamic) check stiffness of a subgrade / subbase / base course structure as a performance indicator. This structure is much larger than a CBR sample and, quite often, made from a material mix. When using the standard LWD set-up of a 300mm base plate and a 10kg falling weight, you measure the elastic deformation of approx. 45-60 centimetres of soil underneath the plate. So, the information you get is about the performance of a mass of around 30 kg of all material layers combined beneath the surface to that depth.

Depending on material mix, compactablity, moisture content and the compaction effort applied, the soil retains a certain elasticity under a dynamic load. Evd thus tells you, how this soil will perform under load. So, you will know whether or not this is compacted well enough to withstand targeted dynamic loads. During compaction, Evd also helps you understand if the material mix is ok and if compaction efforts thus will lead to the results you want.

Despite the fact that there is no general mathematical relation, some researchers have been able to established correlations between CBR and plate loading tests empirically.

Below are two older examples from German literature. Authors are a) Prof. Dr. Wolfgang Weingart and b) Prof. Dr.-Ing. Rudolf Floss. Both completed extensive research in this field throughout the 1970's and 1980's.

They both found different relations between CBR and Ev2 (static plate test) values for different materials.

Ev2 versus Evd is another topic but for the purpose here, you can divide the Ev2 value in the pictures or tables by two (2) to get the approximate Evd value measured with a ZORN LWD.

a) Collection of different correlation factors that WEINGART summarised from various pieces of literature:

WEINGART (1998) stellt aus Literaturangaben die ermittelten Zusammenhänge zwischen dem CBR-Wert und dem E_{V2}-Modul zusammen, die in Abbildung 3.4 dargestellt sind.

Soweit angegeben, liegen folgende Kurvengleichungen vor.

1. $E_{V2} = 7{,}5 \cdot CBR^{0,75}$ (bindige und nichtbindige Böden)
2. $E_{V2} = 20{,}35 \cdot CBR^{0,5}$ (nichtbindige Böden)
3. $E_{V2} = 6 \cdot CBR^{0,8}$ (bindige Böden)
4. $E_{V2} = 10 \cdot CBR^{0,73}$ (Shell)
5. $E_{V2} = 17{,}6 \cdot CBR^{0,64}$ (TRRL, bindige Böden)
6. $E_{V2theor} = 9{,}9 \cdot CBR^{0,77}$ ($E_{V2theor}$)

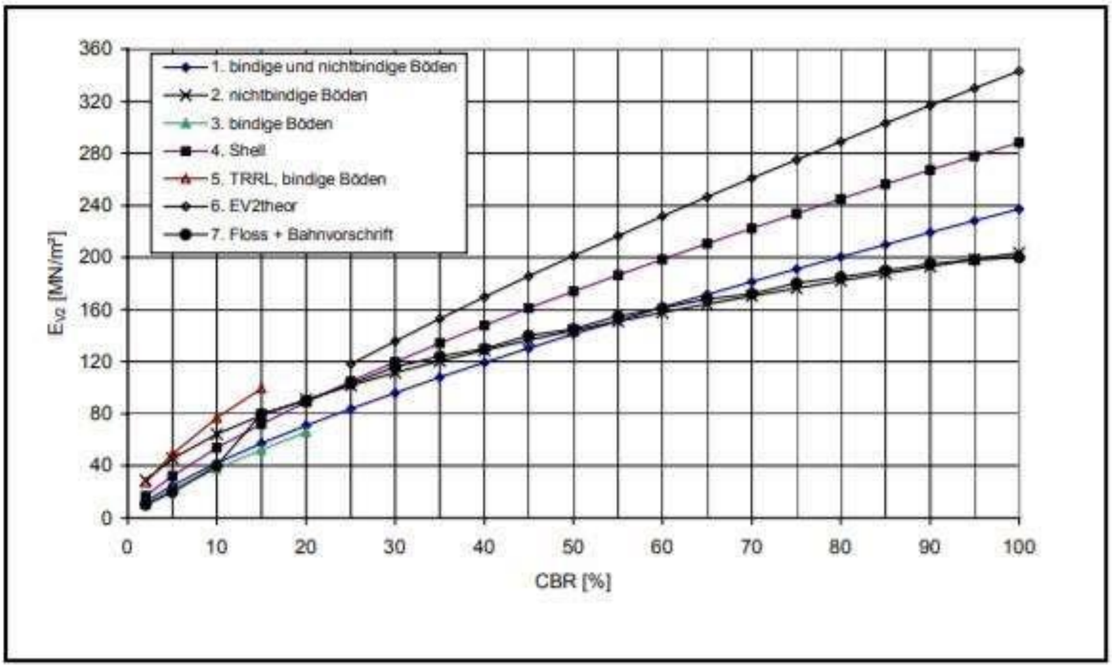


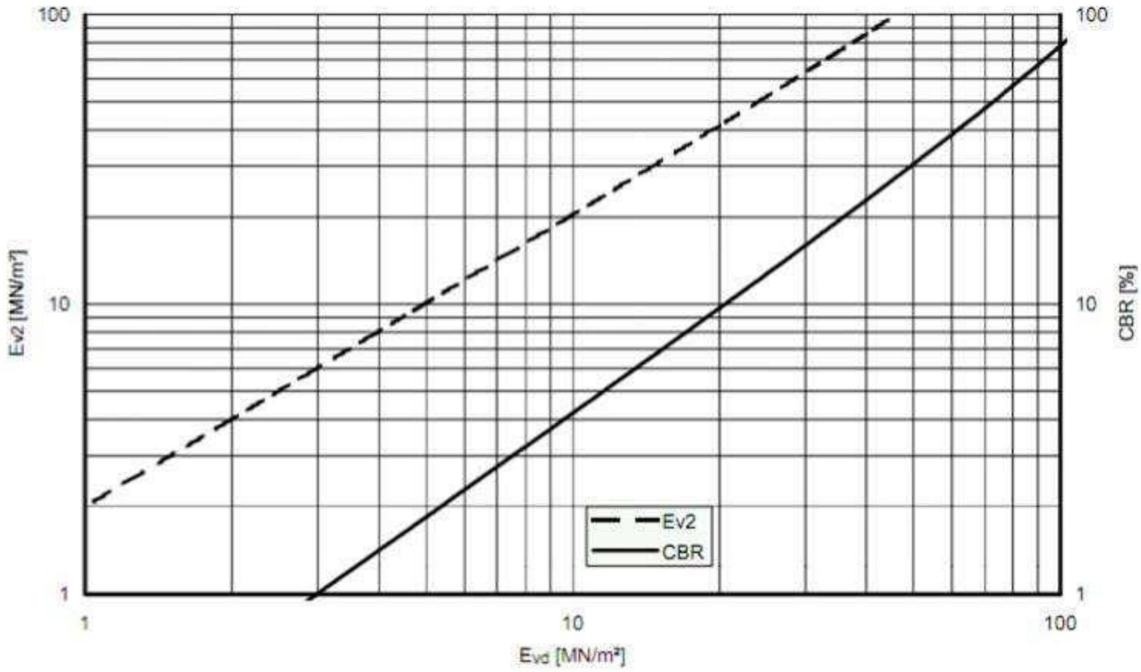
Abbildung 3.4:
Relation zwischen CBR-Wert und Verformungsmodul E_{V2} (von WEINGART 1998 aus Literaturangaben zusammengestellt)

Also based on WEINGART is the example below for a base course made of unbound crushed rock and gravel mix. The graph of Ev2, Evd and CBR is a theoretical relationship based on optimum material. In practice, you have to evaluate the relationship of real existing soils. There is no general relationship.

The empirical equations to derive the graph plot are as follows:

Ev2 = 2 x Evd

The graphed results for CBR assume the optimum water content with test done in the laboratory. The moisture content of samples are given by mass % of water and are not soaked.



The CBR / Evd relation can be seen on the right side from the full Evd line (e.g., 10% CBR is equivalent to 22MN/m2 Evd). In addition, you have the relation between Evd and Ev2 for the static plate load test on left from the full Evd line. (Evd 22MN/m2 ~ Ev2 45MN/m2 ~ 10% CBR).

Note: Prof. Dr.-Ing. Wolfgang Weingart was instrumental in the development of the Anix Plate Load Test and Zorn Light Weight Deflectometer.

b) A table set-up by FLOSS with correlation values for cohesive (“bindige”) and non-cohesive (“nichtbindige”) soils. Non-cohesive are all soils types with a portion of binding materials lower than 15%

CBR [%]	E_{V1} [MN/m²]	E_{V2} [MN/m²]	
		bindig	nichtbindig
2,0	6,6	10,7	-
3,0	9,0	15,0	-
4,0	10,9	18,5	-
4,5	12,0	20,0	-
5,0	12,9	22,0	43,0
5,6	14,0	-	45,0
6,0	14,6	24,5	47,0
6,2	15,0	25,0	-
7,0	16,2	27,5	50,0
8,0	18,0	30,0	-
9,0	19,5	33,0	58,0
9,6	20,5	-	60,0
10,0	21,0	35,0	61,0
13,6	27,0	45,0	-
15,0	28,3	-	76,0
16,4	30,0	-	80,0
20,0	35,0	-	90,0
24,0	40,0	-	100,0
30,0	46,5	-	112,0
34,0	51,0	-	120,0
40,0	57,5	-	131,0
50,0	68,0	-	147,0
85,0	100,0	-	187,0

Tabelle 3.3:
Relation zwischen Verformungsmodul E_V und CBR-Wert (FLOSS 1973)